SOUTH DAKOTA GEOLOGICAL SURVEY.
BULLETIN NO. 2.

THE FIRST AND SECOND BIENNIAL REPORTS

ON THE

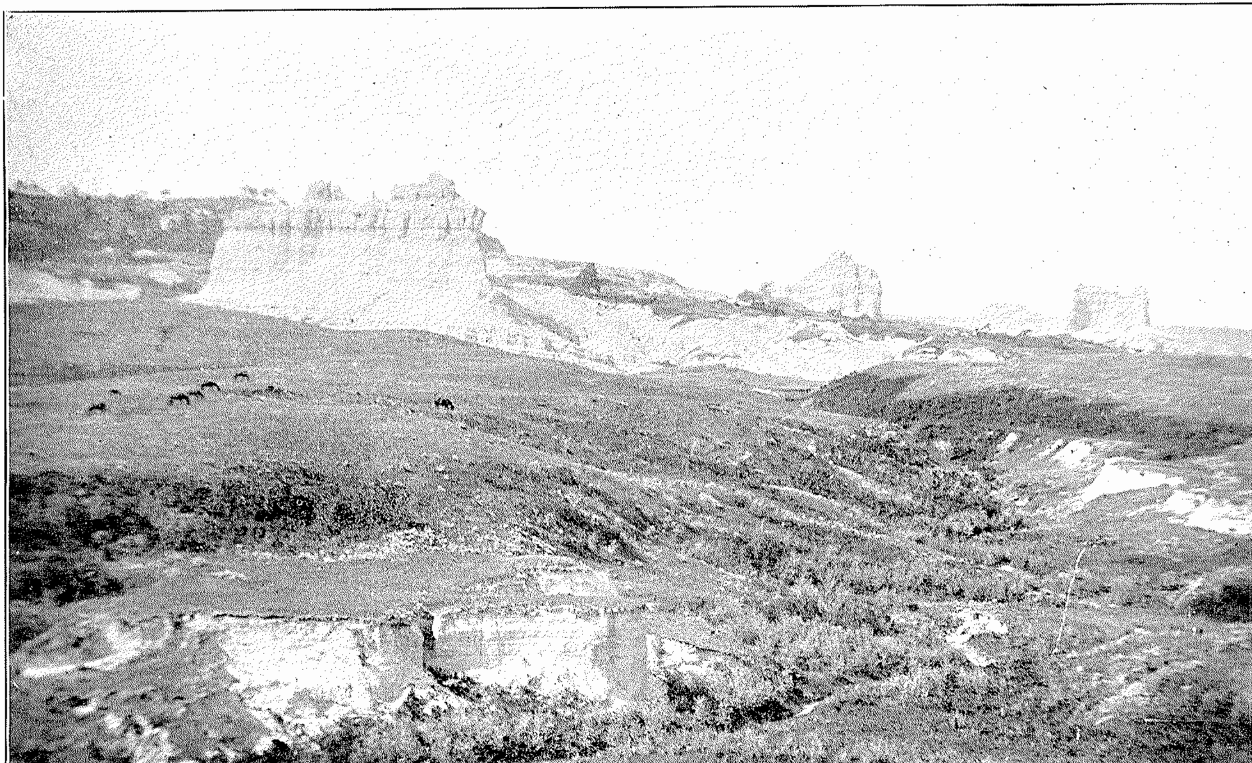
GEOLOGY OF SOUTH DAKOTA

WITH

ACCOMPANYING PAPERS.
1893-6.

JAMES E. TODD, M. A., F. G. S. A.
STATE GEOLOGIST.

Vermillion, S. D.
The Dakota Republican.
1898.



Castellated Buttes near the North Gap of the Slim Buttes.

LETTER OF TRANSMITTAL.

UNIVERSITY OF SOUTH DAKOTA,
VERMILLION, S. D., Dec. 12, 1894.

Hon. H. H. Blair, President of the Regents of Education:

DEAR SIR:—I herewith submit Bulletin No. 2, of the Geological Survey of our State, which includes the First and Second Biennial Reports of the State Geologist, with accompanying Papers.

This has been prepared with the expressed consent of your honorable body, in order to keep our citizens posted, not only with reference to the aims of the survey, but to give them as early as practicable the results of our investigations. It is sincerely hoped that they may be found of such interest and practical advantage that the survey may be more liberally supported in the future, that the remarkable natural resources of our great commonwealth may be speedily understood and efficiently utilized.

I would call attention to the fact that, even this result, meagre as it is, has been accomplished by supplementing the regular appropriation for the survey by quite a sum from the appropriation for the School of Mines, besides considerable gratuitous service.

Very respectfully yours,

J. E. TODD,
State Geologist.

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PREFACE.

As has been noted in the sketch of the history of the Survey on a following page, the bulk of this work consists of material prepared two years ago to be published with the second Biennial Report of the State Geologist. On account of the delay, which is also explained there, it has been found advisable to revise to a considerable extent. This revision will account for some possible discrepancies that may have crept in. It is believed, however, that most have been discovered and are corrected in the Errata. The survey has issued heretofore but one publication, viz., Bulletin No. 1. It was at first proposed to have this publication the first of another series to be printed in a more permanent form. It was early found, however, that this was beyond the means available, and consequently it is issued as Bulletin No. 2. This explanation will account for the form in which some of the material is found. Moreover some of the papers have been abridged in order to bring them within the necessary financial limit. This is particularly true of the last article. Numerous sections had been prepared that should give a detailed presentation of the geology of the localities visited, but it was found unadvisable to publish them. The same is true of a number of illustrations that have been prepared. This fact is not without its advantages, for it is to be hoped that opportunity will be found for re-examination of the ground and more reliable conclusions be arrived at. An omission to be particularly regretted is that of a valuable paper by Prof. F. C. Smith, formerly of the School of Mines. This was largely due to this reason, but also in part to unavoidable delay in preparation of it. Another reason for issuing this as a bulletin, rather than as the first of another series of volumes, is that it is hoped that more liberal appropriations will enable us to present our reports in a way more befitting the magnificent resources which we have to announce to the world, and a form more convenient for the accurate presentation of the subject.

Had we endeavored to begin the work upon such a plan, we should have been unable to prepare more than a small part of the first volume.

Since the presentation of our second report, the United States Survey has taken up the examination of the Black Hills and also an investigation of our artesian supply in a liberal manner, and the public is referred to the results, so far as yet published, in lieu of what we had hoped to accomplish as a State Survey. The material thus far issued is as follows: 1. Topographic sheets covering the most of the Black Hills and also most of the James River Valley. Each sheet covering a quadrangle, so called, one-half a degree of latitude in length, and one-half a degree of longitude in width, may be obtained for five cents, by sending to the Director of the U. S. Survey. 2. Preliminary reports on our artesian resources, which have been prepared by Mr. N. H. Darton, and published in the 17th and 18th Annual Reports of the Survey. The first report, which is the more complete, has been also printed separately and may be obtained by applying to Congressmen. We may take this opportunity also of informing those interested in the subject, that the government has further published concerning our State as follows: the War Department has published a map of the Missouri River on the scale of one inch to 1000 feet, giving also the altitudes of points within the immediate valley, including the soundings of the stream; the Missouri River Commission has published a map of the Missouri River, including the portion within our State on a scale of one inch to the mile.

The Experiment Station at Brookings in Bulletin No. 41 gives the analysis of waters from representative artesian wells of the main artesian area.

In the performance of our work we have received numerous favors from the citizens of the State and others, the most important of which we have attempted to acknowledge in connection with the papers presented. Beside them, we have received numerous small favors from persons not mentioned, but to whom we are likewise grateful for the assistance they have afforded in the great work upon which we are engaged.

HISTORY OF THE SURVEY.

In the readjustment of the affairs of the State University in 1892, President J. W. Mauck, then lately called to his position, strove to make it not only an educational institution of first rank, but to also make it as early as possible a center for original research for the benefit of the State.

He was quick to perceive that no provision had yet been made for the exploration of our natural resources. Aware that most states of the Union had supported geological surveys to their great advantage, and especially familiar with the excellent results obtained in our neighboring state, Minnesota, he set about securing a similar organization for South Dakota.

Largely by his personal effort, a bill modeled closely after that of Minnesota, was prepared and adopted at the third Session of the State Legislature. It was as follows:

CHAPTER 98.

[S. B. 286.]

PROVIDING FOR A GEOLOGICAL SURVEY OF THE STATE.

AN ACT to Provide for Surveys of the Geology, Natural History and Physical Features of the State.

Be it Enacted by the Legislature of the State of South Dakota:

§ 1. ~~DUTY OF REGENTS OF EDUCATION.]~~ It shall be the duty of the regents of education ~~to~~ cause to be made as soon as practicable, surveys of the geology, natural history and physical features of the State.

~~§ 2. SURVEYS—WHAT TO INCLUDE.]~~ Said surveys shall be carried on with a view to a complete account of the mineral, vegetable and animal kingdoms, as represented in the state, together with its physical features, including the several geological strata, ores, soils, clays, coals, peats, artesian and other waters, marls, building and other stones and cements and other useful minerals and materials, scientific analysis of said materials, and report upon their economic value, accessibility, and further including tests by drilling, digging or other excavation for the discovery of water, iron, silver, gold, copper, coal, gas, salt or other valuable mineral or other material that may from said surveys, appear likely to exist in the state. Said surveys shall further have in view a complete and scientific account of the vegetable and animal kingdoms of the State, including all native and naturalized grasses, herbs, plants, shrubs and trees, insects, birds, reptiles, fishes and mammalia.

216 § ~~3.~~ ~~REGENTS TO PROCURE GEOLOGICAL MAP.]~~ The ~~said regents~~ They ~~of education~~ shall cause a geological map of the state to be made as soon as may be practicable, upon which the various geological formations shall be represented, and

16 § 4. ~~REGENTS TO PROCURE GEOGRAPHICAL AND OTHER MAPS.]~~ ~~The said regents of education~~ shall also cause to be ascertained by barometrical and other observations, the elevations and depressions of different parts of the state; cause to be tabulated such meterological and other observations and statistics as may be required to account for the variety of climate and products of the various parts of the state; and cause to be compiled, as soon as practicable, an accurate geographical, physical and topographical map or maps of the State.

217 § ~~5.~~ ~~DUTY OF REGENTS IN CARE AND COLLECTION OF SPECIMENS.]~~ The Said regents of education shall cause suitable specimens, properly prepared, secured and labeled, of all soils, rocks, ores, coals, peats, fossils, cements, building and other stones, plants, woods, skins and skeletons of animals, birds, insects and fishes, and other mineral, vegetable and animal substances and organisms discovered or examined in the course of said surveys, together with the reports upon all chemical or other scientific analysis made in connection with said surveys, and the results of all meterological, barometrical and other observations and statistics, to be preserved for public inspection, and whenever the same may seem to be practicable, cause duplicates in reasonable numbers and quantities, of said specimens, reports and results, to be collected and preserved for the purpose of exchange with educational, scientific or other institutions, of which the Smithsonian Institute at Washington, in the District of Columbia, shall have the peference; and for the purpose of such donations to scientific institutions of this State, as shall by the said regents of education be deemed proper.

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218 § ~~6.~~ ~~REGENTS TO SUBMIT REPORT TO GOVERNOR—WHAT TO CONTAIN.]~~ No person appointed or employed to carry out the provisions of ~~this act~~ shall incur any expense or make known the results of his investigations, except as authorized by the said regents of education. All persons so appointed or employed shall immediately report to the said regents of education all discoveries of economic or scientific interest to the state in general and shall make, on or before the first ~~day~~ of November next preceding each regular session of the legislature, a complete report of the progress of said survey, accompanied by such maps, drawings, tables and other specifications and exhibits as may be proper and necessary to exemplify the same, and it shall be the duty of said regents of education on or before the ~~first~~ day of ~~December~~ next preceding each regular session of the legislature, to submit the aforesaid report or reports to the Governor, who shall lay the same before the legislature, and the said regents of education, upon the completion of any separate portion or department of the said surveys, shall cause to be prepared a report which shall embody all useful and important information accumulated in the investigation of said portion or department, which report shall likewise be conveyed through the governor to the legislature.

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§ 7. APPROPRIATION.] To carry out the provisions of this act, the sum of two hundred and fifty dollars per annum is hereby appropriated, to be drawn and expended by the said regents of education.

§ 8. REPEAL.] All acts and parts of acts in conflict with the provisions of this act are hereby repealed.

Approved March 6, 1893.

The Regents of Education at their meeting at Brookings, March 9, 1893, on motion of Mr. F. G. Hale, took the following action:

WHEREAS, a recent act of the legislature makes it the duty of this Board to provide for surveys of the geology, natural history and physical features of the State, and makes an appropriation;

Therefore, Be it resolved, that the Professor of Geology and Mineralogy at the State University, be and is hereby elected State Geologist to carry out the purposes of said act, and that he be authorized to expend sums so appropriated for purposes contemplated by said act, the same to be drawn on vouchers approved by the Treasurer of this Board.

By virtue of this action Professor James E. Todd, A. M., became State Geologist. The small appropriation made did not admit of any extended organization or elaborate effort.

A little was attempted by correspondence to collect data and to interest citizens in the work. The State Geologist had already acquired considerable acquaintance with the eastern part of the State in his employment for several seasons by the U. S. Geological Survey. To supplement this he took a short trip to the Black Hills and the Bad Lands that he might intelligently interpret the observations of others in that portion of our State and prepared for publication Bulletin No. 1, of the State Survey, entitled, "A Preliminary Report on the Geology of South Dakota." This was issued early in 1895 and mainly at the expense of the State outside of the Geological survey appropriation.

Hoping that something of the same sort could again be done the most of the material for the present volume was prepared that it might be issued early in 1897, but by an unfortunate combination of circumstances it was rendered impracticable.

As the separate articles herein will explain themselves it is not necessary to sketch the history farther. Notice is simply called to the First and Second Biennial Reports which are here presented to the public for the first time and may be found specially helpful in indicating the aims thought to be most feasible, and what might be done if means were supplied.

First Biennial Report

Of the State Geologist.

To the Honorable Board of Regents:

GENTLEMEN:—By your favor, the duties of State Geologist were laid upon me more than a year ago. The law, establishing the survey, requires a Biennial Report to be made by the State Geologist before the first day of November next preceding the regular session of the Legislature, hence this communication.

Nearly a year elapsed after my appointment before circumstances permitted me to undertake active work. This delay resulted from two reasons: one, the existence of a previous engagement with the State Geologist of Minnesota, which occupied my summer vacation of 1893; the other, the fact that the annual appropriation is so small that it seemed economical to unite, so far as possible, the appropriations for the years 1893 and 1894.

After consultation with the President of the Board of Regents and other members, it was concluded that one of the first steps toward the carrying out of the purpose of the survey would be to prepare a short public statement of what is already known concerning the geology of the State. This would furnish a starting point for the gathering of additional data. It would tend to arouse interest in the work among our citizens, and at the same time would bring within the reach of all interested a large amount of valuable information, which has accrued from the various investigations made by the Government Surveys, which have traversed our State, and more recently by special students who have visited it. This of itself would be of great public interest and economic value.

To accomplish this it was planned to prepare a preliminary geological map with a complete description of the characteristics, extent and economic importance of the various geological formations in our State, with such illustrations as should be found available. This preliminary report on the geology of the State, it was planned to issue as a bulletin as soon as practicable. To make this more complete and accurate it was planned for the State Geologist to take a short trip to the Black Hills and the Bad Lands, in order to better interpret and judge of the statements of previous observers. This could not be undertaken until after the close of the University year in June.

My official duties, meanwhile, were mainly confined to correspondence with various parties inquiring concerning the geology of the State and in asking inquiries of reliable parties concerning points in our geology. Since his appointment the State Geologist has received eighty-seven letters of inquiry and of information concerning geological matters, from fifty-five different correspondents. These have included capitalists, inquiring concerning the resources of the State; citizens, endeavoring to learn the prospects of obtaining artesian wells, building stones, materials for cement, etc.; and others inquiring concerning interesting specimens and facts found in their vicinity. These letters, of course, represent an equal number written in reply.

I also attended a convention called at Huron, March 7th, 1894, to consider the interest of the State so far as concerned with the subject of irrigation and artesian wells. Here I presented a paper upon the geology of our artesian basin, and was appointed chairman of a committee to prepare a paper for publication upon the water supply of the State and methods of economizing and utilizing it. Other communications furnished officially to the papers of our State are as follows: a communication to the State Engineer on "The Extent of the Artesian Basin," was published, with his report. A communication to the Volante of the State University on "The Adequacy of the Artesian Supply," appeared in May and was copied in the Dakota Farmer. Another paper on the same subject was published in the Recorder of May 15th and the Journal-Observer of May 10th. I have also prepared a short paper on "Our Smaller Artesian Areas" for the Pierre Capital, and also a short statement on "The Limits and Adequacy of our Artesian Supply," to be published with a bulletin of the Agricultural College, now in preparation.

As soon as practicable after the close of my regular duties in the University last June, I proceeded by rail via Sioux City, and Chadron, to the Black Hills. I arrived at Buffalo Gap early in the morning of June 21st. A short reconnoisance was made to Wind Cave, whose worthy proprietor, Mr. J. D. McDonald, kindly entertained me and gave me every facility in his power for examining that most interesting cave and the geological formations in its vicinity. Returning to Buffalo Gap after a rapid examination of the geological formations exposed along Beaver Creek, I proceeded by rail to Rapid City. There I found a favorable opportunity to drive across the country to Hill City, thus obtaining another view of the several formations constituting the Hills.

After ascending Harney Peak and studying rapidly the formations between Hill City and Keystone, I returned to the former place and proceeded by rail to Deadwood. There I met Prof. F. R. Carpenter, formerly Dean of the School of Mines at Rapid City, and a careful student of the Hills. He kindly assisted me in various ways. While connected with the School of Mines he published for the State "A Preliminary Report on the Geology and Mineral Resources of the Black Hills." He informed me that much additional work had been put in manuscript, and was left by him at the School of Mines; also that this manuscript was properly the property of the State. He gave me several valuable references to localities of interest, and to individuals, who would be interested and helpful in my work. After spending two days about Deadwood and Lead City, I returned to Rapid City to attend to correspondence and close up the financial work for the year.

Having been disappointed in the plan I had previously made to enter the Bad Lands with a land surveying party from the South, on account of an unexpected change in their plans, I engaged a young friend, Mr. D. O. Cleghorn, to take his team and wagon and spend about two weeks with me in the region of the Bad Lands.

While he was perfecting arrangements I took a short trip to Piedmont and Crystal Cave to examine the latter and the geology of Elk Creek Canon. Mr. Mac Lamore, the custodian of the cave, kindly showed me its many attractions. I returned to Rapid City July 4th.

We started July 6th and proceeded by the usual road to Smithville, at the junction of Elk Creek and Cheyenne River.

In that vicinity we spent a day in collecting fossils. I then proceeded on the "Pierre Trail" eastward twelve or fifteen miles, making note of the terraces and other features of the surface geology. Thence we turned South and Southwestward across Cotton-wood creek to the "Great Wall" near Sage Creek Pass; in the western part of Tp. 1 S., R. 17 E., and spent three or four days in exploring and collecting fossils from the Bad Lands. We then went down through Big Foot Pass to the lower level near White River, to Black. Thence we followed the Chamberlain trail to Rapid City, where we arrived July 19th. There I boxed and shipped the fossils and minerals collected, which weighed over four hundred pounds. During my visits at Rapid City I formed pleasant acquaintance with Dr. McGillicuddy, present Dean of the School of Mines. He kindly interested himself in our work; he has since made unavailing search for the manuscript spoken of by Prof. Carpenter, and has also placed in my hands several plates used in the publication of Prof. Carpenter's first Report. These may be found of value in the publication of our proposed bulletin.

The time which I could devote to field work had nearly expired. I remained in the Hills only long enough to visit Hot Springs and vicinity for a day.

I reached Vermillion July 22d. Certain business for myself required my time for about two weeks. But early in August, I went to work diligently to prepare the manuscript for the preliminary report on the geology of South Dakota. This work I attended to, until I learned that it was questionable, whether the firm, with whom I had contracted for the printing, would be allowed by the State Printers to do the work. Seeing that if the printing should cost more than the low figure at which it had been contracted, the geological appropriation would be insufficient to finish it this year, I concluded to let the work rest. Early in October, after the meeting of your Committee on the Geological Survey, I was directed to proceed and finish the bulletin; and since that time I have been prosecuting the work as assiduously as my duties in the University would allow. About 190 pages typewritten manuscript are already finished, which comprise four-fifths of the work as planned.

Twenty-five hundred copies of the geological map of the State have already been printed.

The following is a statement of the expenditures of the funds appropriated for the Geological Survey:

Amount appropriated for the year ending June 30, 1894,......		$ 250.00

EXPENDITURES.

For Stationery—1000 Envelopes, ...	$ 5.50
Trip to the Cement Works in Yankton, ...	1.60
Expenses to the Huron Convention, March 7, ...	8.60
For 2500 S. D. Maps, 11x14, (of Rand, McNally & Co.)............	25.00
For printing in colors of same, to Aug. Gast & Co.,............	85.00
To the State Geologist for services during the year,...........	50.00
For two 1000-mile tickets,..	50.00
For field expenses, June 19th to 30th,............................	15.85
Amount drawn on contract for printing, for material,.........	8.45
Total,...	$ 250.00
Amount appropriated for the year ending June 30, 1895,.......	$ 250.00

EXPENDITURES.

Field expenses, July 2d to 23d, ...		$ 47.95
For express on maps from Gast & Co., ...		1.90
Paid Stenographer, (not yet drawn),...........................		20.00
Total, ...		$ 69.85
The balance remaining would be		180.15
Possible rebates for money paid printer for material,....	$ 8.45	
For the amount on the 2d 1000-mile ticket, unused,........	17.50	25.95
Amount available for the rest of the year,....................		206.10

If no larger appropriation is possible for another year, it is suggested that what we have will be most profitably spent in two short exploring trips. One for exploring more carefully the region between White River and the south line of the State; and the other for exploring the region in the northwestern corner of the State. The object of the first would be to learn more definitely the age and nature of the deposits in that region. Its economic bearing will be to determine the general topography and nature of the soil, and particularly the probable thickness of the rocks overlying the water-bearing Dakota sandstone; and incidentally to collect fossils from the Bad Lands. The object of the second will be to similarly explore the northwestern corner of the State which probably contains valuable beds of lignite. Ground for this supposition is based upon its relation to the recently opened mines in eastern Wyoming and those west of Bismarck on the North. Moreover, the report of Prof. N. H. Winchell of his observations with the expedition of Captain Ludlow in 1874, informs us that he found beds of lignite 3 to 8 feet in thickness, about the upper waters of Grand River. The U. S. Geological Survey explored the region further to the east, between Rabbit Butte and Flint Creek, and reported beds about two feet in thickness, but of little or no economic value. It seems not improbable, therefore, that the more valuable beds are farther west. Considering the fact that this northwestern region has been less explored, and that it lies outside of Indian Reservations, it might be profitable to concentrate our energies upon that part, leaving the other region until a later time. This reconnoissance may be advantageously made during the coming season.

Should a larger appropriation be forthcoming, several important practical problems await the attention of the State, with greater or less urgency.

1st. To determine the extent and adequacy of our artesian supply. Although the character and distribution of the water formation is remarkably simple, several factors of the problem have not yet been determined. And although to fully solve the problem we must have the co-operation of sister States, or the general government, there are several things we must do as a State. Some of these are purely geological and some may more properly belong to the State Engineer. It matters much less by whom it is done, than that it should be done. The work of a geological character, which may be helpful is as follows:

a. An examination of available borings, particularly those of test or typical wells, to determine the lower limit of the Dakota Formation, or the surface of the underlying Archean rocks, and so to determine the lower limit of water-bearing strata. There are frequent reports of striking granite and quartzite, which are to be received with allowance. Uncertainty upon this point works evil in several ways. It may lead to the loss of much valuable work, by stopping an enterprise too soon; and on the other hand, when such mistakes have been discovered a few times, it weakens faith in such claims when justly made, and leads to lack of confidence, waste of money by foolish borings and by litigation. The expert examination of a test well in a locality might settle forever the point whether an artesian flow can be obtained there or not. A needy people uninformed and unconvinced are liable to be led astray by a crafty or ignorant well-borer, not simply once, but again and again. It will, also, tend to protect the well-borer from unreasonable requirements.

b. Another important point is to determine whether the different water-bearing strata usually struck in boring are distinct from one another, or whether they are connected more or less. This may perhaps be made out by comparing records of different wells; and this can be best done by a geologist experienced in distinguishing formations and familiar with the distribution of the same.

c. Another thing is to determine the location and extent of the outcrops of the Dakota Formation and to learn how the water enters it, the conditions which affect it, etc. On the other hand, if there is a leak, it is the work of the geologist to discover and measure it.

The points which more properly belong to the Engineer are as follows:

d. It is of the greatest importance that a careful record be kept of the pressure in the various artesian wells in the different parts of the State. This should be done carefully and through a long period. The importance of this cannot be too strongly emphasized. All estimates of the adequacy, and the proper regulation of both the locating and management of wells, must depend chiefly upon this. This seems to be the rational basis for prognosticating the duration of this wonderful resource of our State. Without that we may be as foolish as the man that killed the hen that laid the golden egg.

e. Another work calling for the experience of an engineer is a careful gauging of the streams about the Black Hills both before and after they cross the Dakota sandstone, that we may obtain evidence whether water enters that formation at this point and, if so, how much, and what conditions may increase it. It may be, that we, as a State, have our hands, as it were, on both ends of the business, and that we may intelligently and successfully increase and perpetuate our artesian supply.

2d. Another promising field of investigation is the study of the schists and slates of the Black Hills. Heretofore most geologists have taken the slaty lamination of the rocks as indicating their primary bedding-planes of deposition. This has therefore been considered more or less in locating mineral and other deposits in the Hills. Within a few years this view has been generally questioned and certain clear traces of original sedimentation have been detected. Instead, therefore, of there being exposures in the Black Hills of one series 100,000 feet in thickness, as was first reported, it is very probable that the original formations, instead of being of such fabulous thickness, are much thinner and are folded and repeated, we know not how many times. Now if certain of these formations are the main source of certain minerals, an elaboration of the present arrangement and distribution of these folds may be of inestimable value in tracing the various rich ore deposits in that region. Instead of a hap-hazard search, or according to some fanciful rule of distribution, we may, by working out this arrangement of strata, find a key which will guide us readily to the very deposits we seek. At the present time the opportunities for a rational solution of this problem are better than ever before. The value of such stratigraphic knowledge is usually acknowledged in the search for coal, iron and building stones. We know not, until it has been tested, how valuable it may be in the discovery of richer ores and more precious stones. Even veins often derive their inclosed mineral deposits from the adjacent rocks.

3d. A careful study and classification of our soils should be entered upon as early as practicable and reports made from time to time. The possibilities of such research cannot be foretold, but we have every reason, to expect them to be of incalculable value, for this is the foundation of our future prosperity more than our mining resources. This investigation will be greatly assisted, on the one hand, by the knowledge of the underlying geological formations, which cannot be fully determined, until an advanced stage of the survey is reached. On the other hand, much assistance may be expected from the study of the soluble minerals which we mention further on.

4th. We have already referred to our probable deposits of mineral fuel. These should not only be ascertained but their quality and distribution worked out in detail.

5th. An examination of our clays, cements and building stones, should be prosecuted as rapidly as practicable, and reports made upon their qualities, quantities and distribution.

6th. The soluble minerals which are found both in our soils and surface waters and in our artesian wells should be carefully studied. Not only their composition and their distribution but their affect on soils and upon vegetation. While this merges into the field of agriculture, and the work has already been wisely undertaken by our Agricultural College, it is largely based on geology and properly should be more or less classified with the Geological Survey. It seems probable that these mineral salts, which in certain localities are unusually abundant, may be utilized to advantage, or at least some of their deleterious effects be averted.

But I forbear. The work, in thought, grows apace; and the need of study and research may be so magnified beyond our means for carrying them on, that it may hinder our undertaking it. Some may be ready to say that until we have abundant means it is idle to begin it. I have spoken of the various points mentioned rather to call attention to the vastness of the resources of our State and the probable benefit that may accrue, in proportion to the means and efforts expended in their development. A little done may prepare the way for more.

Thus far I have spoken mainly from an economical standpoint. But there are considerations of perhaps higher interest and importance. We have within our borders a great range of geological formations, which are an important part of the record of the past history of our earth and of the origin of life now dwelling upon it. These subjects are valuable for our instruction and for the enlargement of our minds. To do our part as a State in increasing the treasures of knowledge and thus add to the intelligence and happiness of the world is indeed a worthy aim. In the region of the Bad Lands, as you are aware, are rich deposits of remains of strange and most interesting prehistoric animals. The locality is annually visited by students from distant parts of the world to collect and carry away that, which many value more than gold. We shall be untrue to the higher interests of our State and its future inhabitants, if we fail to obtain and preserve our share of this inheritance, which nature has placed within our reach. We therefore should use all due diligence in collecting and distributing to our institutions these most interesting fossils.

Hoping that means may be speedily forthcoming for the proper setting forth of these sources of wealth and knowledge within our State, I am,

Very Respectfully, Your Servant,

J. E. TODD,
State Geologist.

THE STATE UNIVERSITY,
Vermillion, S. D., Oct. 29, 1894.

Letter Introducing the Second Biennial Report.

To the Honorable Board of Regents:

GENTLEMEN: According to the requirements of the law instituting the South Dakota Geological Survey, I have the honor of submitting, herewith, my Second Biennial Report of the same.

As there is no provision yet made for the publication of the various papers referred to in the report, and as it has been impracticable to present them at this date, with your consent they are delayed. Some are already written and the remainder are so nearly ready that they can be promised to be in your hands by January 1st. The following is a list of them with their probable lengths and illustrations:

A Progress Report on the Rapid Creek Section of the Black Hills; 25 pages, 4 illustrations.

Report of a reconnoissance in the Northwestern counties of the State; 35-40 pp, 5 ills.

A Report on our Artesian Basin; 10-12 pp.

Report of a Reconnoissance through the Southern counties of the State and the Bad Lands; 20-25 pp, 4 ills.

Hoping that the work done will be found satisfactory by yourselves and by our citizens, and that the recommendations and estimates will be considered reasonable and moderate, I remain,

Very Respectfully, Your Servant,

J. E. TODD,
State Geologist.

STATE UNIVERSITY,
October 31st, 1896.

Second Biennial Report

Of the State Geologist, 1895-6.

The lines of work engaged in may be briefly indicated as follows: First, correspondence, including the imparting and collecting of information. Second, exploration and field work. Third, the investigation of our artesian resources.

I. CORRESPONDENCE. The publication of the first bulletin of the Survey accomplished well its purpose in arousing a greater interest in the Survey and acquainting the citizens of our State with items of practical importance. It has been of great help in answering the various inquiries that have come from different parties, and has awakened a growing interest in the resources of our State. Copies have been distributed to the principal schools of the State and also to leading libraries and literary and scientific institutions outside of the State. Twenty-one hundred copies were printed, 500 of which were substantially bound in cloth. There still remain on hand about 130 copies of the cloth edition and 200 of the paper. Many commendatory letters and reviews have been received from various correspondents, some of them from foreign countries.

The correspondence, except where it has taken place with reference to artesian waters has been mainly with the following classes: First, the answering of inquiries of teachers and students. Scores of letters have been received from those who have become interested in some discovery in their neighborhood, or from some question raised concerning our State in their studies; and in several cases important items of intelligence have been obtained. Another class of inquiries have been those from capitalists, both in and out of our State, which mainly concerned the existence or development of certain kinds of resources. Letters have been received inquiring concerning occurrence of building stone, gypsum, marble, coal, graphite, artesian waters, nature of the soil, water-power, etc. A third class of inquiries have been those made by citizens of our State who have either found some unusual deposit upon their lands or have had practical questions connected with the obtaining of water. Expert testimony, also, has been given in cases of litigation.

Another means of spreading information of our resources has been by lectures to teachers' institutes and conventions, and by other public addresses. An additional service rendered by the State Geologist, which has been of no small importance, has been the publication of articles in newspapers. During the past two years some eight or nine have been prepared and quite widely published.

II. EXPLORATION AND FIELD WORK. The close occupation of the Geologist with his duties during the University year, together with the small appropriation, has rendered it impracticable to spend more time in this way than portions of vacations, principally in the summer.

In the summer of 1895, as there was found to be a considerable fund unused, which had been appropriated for the use of the School of Mines at Rapid City, the State Board of Regents, with the approval of the Trustees of that institution, thought it wise to use it in field work. This was done in May and June of that year. Two lines of exploration were carried on. Both were placed under the direction of the State Geologist so that the discoveries and the results of the work should be economically harmonized with the other efforts of the Survey.

One of these expeditions was for the construction of a geological section of the Black Hills along the line of Rapid Creek. The other was for the examination of the region north of the Black Hills, including the Cave Hills and Slim Buttes, with particular reference to the occurrence of lignite and other substances of economic value. The former of these, after having been well begun, was placed under the efficient management of Professor F. C. Smith, of the School of Mines. He was assisted most of the time by five of his students, namely: Will Cumerilh, Charles DuMours, Charles Gardner, Jesse Simmons and Frank Whitehead.

The general stratigraphy of the Paleozoic formations having been worked out and the Archean schists being more mineral bearing, the training of the mining engineer was eminently fitted for the work. Professor Smith continued at the work, moving his camp from place to place, and examined the section as far west as the line of the Burlington & Missouri R. R. at Rochford by the end of June. Much variety of character was found in the slates, and at several points very interesting and complex folds were discovered. Reports of the two principal divisions of this work are submitted herewith.

On the 21st of May, I started with team, driver and camping outfit from Rapid City to explore the northwestern portion of the State, more particularly the region of the Cave Hills and Slim Buttes. About six weeks were spent in examining more particularly with reference to the composition of the Laramie formation, which here as further north, was found to include valuable beds of lignite. Two important geological discoveries were made. First, a development of the White River and Loup Fork formations, 300 or 400 feet in thickness about the Slim Buttes, and traces of them were found in the upper portion of most of the Buttes of the region. Another point of special significance and interest was the discovery of a very pronounced disturbance of strata effecting the Laramie and White River beds and preceding the deposits of Loup Fork. This was particularly manifest in perhaps a score of square miles in the northeastern portion of the Slim Buttes. I reached Rapid City June 29th. The report of this work is also subjoined.

Upon my return, having obtained transportation over the Burlington & Missouri River R. R. in the State, I deemed it important to make a reconnoissance over that line before leaving the field. Ten days in July were spent in this way.

During the winter holiday vacation, a flying trip was taken along the eastern boundary of the artesian basin to determine more accurately that limit. Numerous valuable data were collected from Newark, DeSmet, Madison, etc., and will be preserved for future reference.

In the summer of 1896 an expedition overland across the country south of the White River to the Bad Lands was planned with the double purpose: First, to reconnoiter a part of the State little known geologically, and also to begin a collection of the remarkable vertebrate fossils which are found within our borders.

Among the points of special interest either from a geological or economic stand-point are the following:

First, the discovery of a bed of volcanic ashes along the valley of the South Fork of the White River. This was found to be about ten feet in thickness, extending for ten or twelve miles and apparently marking the interval between the White River and the Loup Fork stages. This, together with a disturbance about the Slim Buttes, noted in a previous paragraph, throws important light upon the time of the porphyry outflows and other volcanic disturbances in the Black Hills, and possibly the latest and principal elevation of the Hills themselves.

Another point of interest is the occurrence of considerable quantities of Baryta at certain horizons of the lower portion of the White River formation. Further investigation may discover workable beds of this material.

Another of the interesting facts learned concerning the Bad Lands is the occurrence of numerous quartz veins traversing the lower portion of the White River formation near the mouth of Porcupine Creek. Attending this deposit are also geodes of considerable scientific interest. Also the quartz in some places is tinted a beautiful blue that may make it of artistic value. Numerous photographs illustrating the remarkable topography and scenery of the Bad Lands were obtained.

Another result was the obtaining of important fossils which it is hoped will form the neuclus of what some time will be an extensive and complete representation of the wonderful fossil deposits of the State. The more careful determination of the formations in the area traversed, together with the thickness and character, are no small part of the results of the work.

Though meeting with some disappointments, the expedition may be counted quite successful.

III. INVESTIGATION OF ARTESIAN RESOURCES. The general interest taken by our citizens in our artesian resources, the many novel and perplexing questions connected with their development, the opportunity which many deep borings afford for learning the geology of the State, and conversely the important help which geological knowledge may give to such development, all have rendered the early study of this subject natural and important. Many letters have been received from citizens, officers of townships and counties and others, both of inquiry and information. Many specimens of borings have been collected. Some of them are of great interest, and in several cases very important facts have been learned concerning the limit of water-bearing strata. Soon after the last report appropriations were made by the general government for sinking deep wells at the Indian Reservations. This was done not only with the hope of obtaining valuable water supplies, but to obtain definite information concerning the distribution and accessibility of water-bearing formations. Correspondence with the United States Commissioner of Indian Affairs prepared the way for hearty co-operation in most cases in the preservation of data and of specimens by parties who sunk the wells. These constitute some of the most instructive and reliable data which have been collected. As the work is not yet ripe for publishing final conclusions, we shall only give in a subjoined paper some of the more instructive data.

A statement of the expenditures of the appropriation made for the Geological Survey, namely, $250 each year as given in the classified summary below:

EXPENDITURES FOR THE YEAR ENDING JUNE 30, 1895.

Transportation, freight, express, etc.,	$ 104.24
For subsistence and camp supplies,	62.20
For postage,	24.16
For typewriting and office help,	44.87
For printing,	3.50
For services,	11.03
Total,	$ 250.00

EXPENDITURES FOR THE YEAR ENDING JUNE 30, 1896.

For transportation,	$ 62.04
For subsistence and camp supplies,	132.00
For postage,	2.67
For printing,	2.00
For services,	51.29
Total,	$ 250.00

About $30 worth of camp supplies are still on hand, in good order.

Although the year 1896-7 has lately begun, the appropriation has already been exhausted. It was as follows:

Transportation, etc.,	$ 177.95
Subsistence,	47.64
Services and sundry expenses,	25.21
Total,	$ 250.00

This leaves nothing to meet the expenses which will necessarily be incurred in the further preparation of the supplementary papers in this report for publication.

WORK WHICH SHOULD BE DONE.

The geologist keeps constantly before his mind the economic aims of the survey. There are numerous lines of investigation which it would be desirable to pursue were the means and time available. It would be well to explore more fully the regions of the State little known geologically. It would pay well to early collect and preserve the data that are being revealed in the development of the older settled portions of the State. It would be well to investigate further the abundance and availability of the lignite in the Dakota and Laramie formations. It would also be desirable to gather for educational and illustrative purposes a choice collection of the remarkable fossils in our borders, and a complete representation of the existing fauna and flora of our State, according to the object of the survey as stated in the law instituting it; but we have felt that the following are subjects very clearly calling for our earliest attention:

ARTESIAN RESOURCES.

Circumstances seem to call for fuller inquiry into our water supplies, including a search after all subterranean streams and springs, but particularly to learn all that may be desirable concerning the origin, adequacy and proper regulation of our wonderful artesian waters. As has been shown in a paper connected with this report, considerable progress has already been made, but it is only a beginning.

The lines of investigation contemplated are the following:

First. To obtain more definite knowledge concerning the extent to which the water-bearing rocks are exposed along the eastern base of the Rocky Mountains and around the Black Hills, Big Horn Mountains and other mountain clusters. This may be learned in part from published reports and by correspondence with reliable parties personally acquainted with the facts, but it seems necessary that some of the most significant localities should be visited and examined with care to determine the extent of such exposures, their relation to topography, rain-fall and streams. For example, the exposures in Colorado along and near the North Platte and around the Big Horn Mountains, and where the Big Horn and Yellowstone Rivers cross the Dakota formation, also perhaps to make closer examinations about the Black Hills than has yet been done.

Second. To make an attempt, by employing experts, if need be, to gauge some of the large streams most favorable for the purpose, to ascertain if possible the loss of water into the rock by seepage.

Third. To learn so far as possible the probable amount of water stored in the water-bearing strata in Wyoming, Montana and other States, which is so elevated as to contribute to the support of our wells in addition to the regular annual supply.

Fourth. To determine as far as practicable the points of leakage and the amounts of the same, also the possible means of arresting or utilizing such leakage. This may perhaps be best done in cold weather when the higher temperature of the waters escaping at those points may assist in such investigation.

Fifth. There may be some decisive light upon the subject of the origin of the waters derived from chemical analysis both of the water of wells or springs and that from streams at certain points along the western exposure of the Dakota formation.

Sixth. It seems not improbable that important light concerning the interpretation of facts of pressure in wells and their relation to amount of supply and leakage may be obtained by experiments not involving very great expense. By some such means it might be possible to determine certain formulae of great practical value for the regulation of our wells. While the remarkable development of our resources has given ground for great expectations, these may have become in some places much exaggerated. Certain speculations have perhaps by some been mistaken for well-grounded conclusions, but the data upon which some general statements have been made are quite meagre. It becomes, therefore, very important that we should learn the true state of the case as fully as possible and as early as possible. Otherwise, we are in danger of unwise use of our resources and possibly of an early exhaustion of that which might with proper regulation be of perennial value.

The United States government through its geological survey is entering upon investigations somewhat akin, if not identical, with those outlined above. How early and how vigorously this investigation may be carried on, we are unable to say. But instead of this being a reason for us as a State to stand aloof and let them carry on the work alone, it is really a cogent reason why the State should take hold, that it may attain recognition in the matter and assure attention to the points of special interest to our commonwealth. And even if these should be somewhat different from those contemplated by the United

States Survey, it is reasonable to believe that the two surveys may be mutually helpful in many ways, if carried on at the same time.

GEOLOGICAL SURVEY OF THE BLACK HILLS.

Another field of immediate importance is the determination of the intricate geology of the crystalline rocks of the Black Hills. The general structure of the hills and the geology of the later formations may be already largely understood, but that of the Archean and eruptive rocks, which are most intimately connected with the precious metals and with ores and economic products of lesser value, has only been looked into. A beginning has scarcely been made toward understanding their structure. Such work was begun by Newton, carried on by Carpenter, Van Hise and others; and Prof. F. C. Smith, of the School of Mines, has recently made very commendable progress in limited localities. It seems just that the School of Mines should be largely utilized in the work, that appropriations may, perhaps, be placed directly in its hands for the work, especially the lines most directly connected with the main purpose of that school; but for the purposes of economy of money, time and effort, such work should be harmonized and unified with the general plan of the survey.

The recently published topographical sheets of the Hills by the United States Geological Survey has removed one of the most serious obstacles in the way of producing an accurate and thorough geological survey of the Black Hills. Although it is understood that the government survey contemplates eventually the elaboration of the geology covered by these sheets, yet we do not understand that this is soon to be realized, and whatever may be done by our State will gain so much time and hasten so much the beneficial results of such work. Moreover, should the general government early take up the work, there may be the similar advantages obtained which we indicated when speaking of an investigation of artesian waters.

It should be remembered that the work in both these lines of investigation may be carried on according to the means which may be devoted to it from the public treasury. That is, it may be either carried on slowly through many years or more rapidly in shorter time.

THE ADVANTAGES OF A LARGER APPROPRIATION.

In closing, I would respectfully bring to your consideration the question whether the time has not come for a very considerable enlargement of the work. The work indicated above cannot be adequately carried on with the small appropriation which the survey has received in past years. It may be noticed that for the present year it is already exhausted in the effort to carry on one short field exploration and that nothing is left for the further work of the year which will necessarily devolve upon the State Geologist by virtue of his position. It will be noticed that much of the work which is reported in the papers subjoined to this report was carried on through means which were appropriated first to the School of Mines. It should be noticed also that the First Biennial Report has not yet been published; and that there is not money at hand for the publication of the present report and its attendant papers; also that the bulletin which has been universally considered of great economic value to the State, was published mainly without the use of the regular geological survey appropriation and that even such publication was much hindered by the fact that suitable illustrations could not be supplied.

Though the advisability of increased appropriation will of course be decided by your judgment, the following estimates are respectfully submitted. Before giving them in tabular form I would notice the importance of some of the items. If the work is done as proposed upon the artesian investigation, the expense of two months field work would be as given below. It should be remembered that it includes railroad fare, board at hotels, the occasional hiring of teams, and the wages of an assistant.

If the work is carried on as proposed in the Black Hills, an equal amount should be allowed for that purpose. This appropriation should be set aside for the geological survey unless it is thought best to place it directly in the hands of the School of Mines. If further investigation is carried on at short times during the regular college year and shorter vacations, it would be well to allow for this work as is indicated. The allowance for help in that connection would be for sundry work in the office and for the teaching of classes during the temporary absence of the State Geologist. As the correspondence is increasing in importance and much writing is needed for the preparation of reports, it is desirable that certain funds should be devoted to typewriting as indicated. Another expense is the purchase of a photographic camera and materials necessary for using the valuable assistance of photography. Certain other instruments would be very helpful in the field. Possibly some may be borrowed from the U. S. Geological Survey, but means should be at hand for obtaining what is necessary. In the estimate for the publication of reports it should be noticed that the request is for a similar appropriation for each of the two years. This is to cover the expense of publication during the first year of reports which have already accumulated, and during the second the expense of preparing the report of the work done meanwhile. An item is introduced for the expense of employing expert work either to be used in the microscopic investigation of the crystalline rocks of the Black Hills or for hydrographic work in the artesian investigation:

For two months' field work, including railroad fares, occasional hiring of teams, wages of assistant and subsistence,	$ 775.00
For occasional work during term time and short vacations, including traveling expenses,	75.00
For assistance in the office, including chemical work, drafting, etc.,	150.00
For instruments, including camera, pressure gauge, current meter, etc.,	75.00
For office printing and postage,	75.00
For services of typewriter,	50.00
For the preparation of illustration and printing of reports,	300.00
For binding 500 copies,	100.00
Total,	$ 1,600.00

Even a larger appropriation than the above could be profitably used.

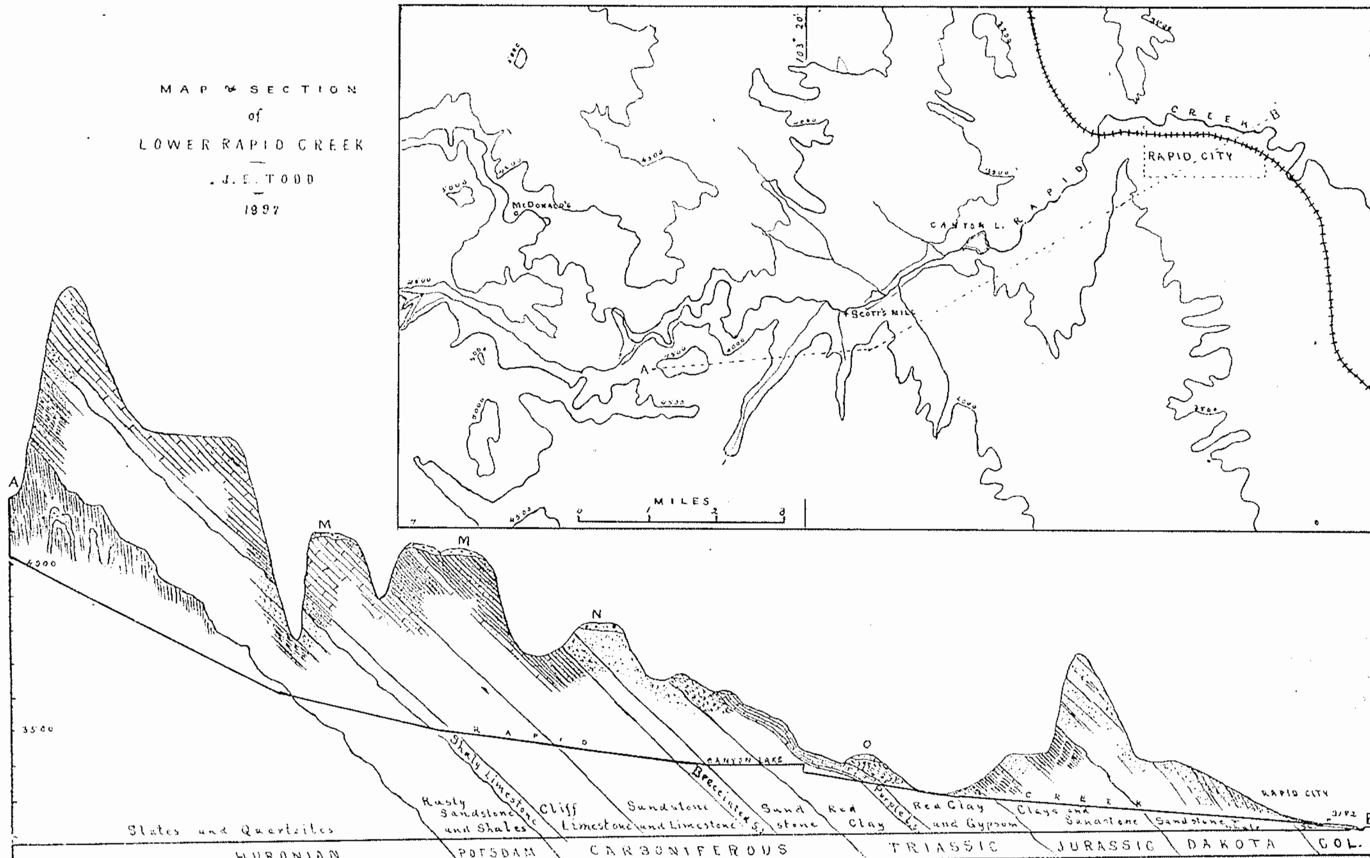
Very Respectfully, Your Servant,

THE STATE UNIVERSITY, J. E. TODD,
Vermillion, S. D., Oct. 31, 1896. State Geologist.

Plate II.

South Dakota Geological Survey.

MAP & SECTION
of
LOWER RAPID CREEK
J. E. TODD
1897



Section Along Rapid Creek from Rapid City Westward.

Early in the month of May, 1895, the Board of Regents of Education concluded to utilize a fund appropriated for the use of the School of Mines at Rapid City, for field work under the direction of the State Geologist. This plan, having been agreed to by the Trustees of that institution, was carried out during the months of May and June. A portion of this work was to construct a geological section through the Black Hills along the line of Rapid Creek.

PURPOSE OF THE WORK.—The aim of this work was to learn the fundamental structure of the Black Hills. In general this was accomplished by Newton as published in 1880 by the United States Geological Survey. The structure has also been further elaborated by Carpenter, Crosby and Van Hise, but many details of unknown extent and importance remain to be developed. This is particularly true of the Archean slates which constitute the core of the Black Hills and are more intimately connected with the mineral deposits of that region. The probable importance of such work to the mining interests of the Hills was pointed out in the last report of the State Geologist.

REASONS FOR CHOICE OF LOCATION.—It seemed particularly desirable to begin such investigations along the line of Rapid Creek for several reasons:

1. It is central and for that reason would be most complete.

2. It is a portion which has not been so carefully examined by geologists and prospectors. Interest has been more centered about Custer City and Harney Peak upon the south and about Deadwood and the late eruptive flows upon the north.

3. Rapid Creek more nearly crosses the Black Hills and has cut down to a greater depth. It perhaps has not as imposing gorges as Elk Creek, but it has really cut deeper.

4. The survey of the Dakota & Wyoming railroad would in this way be utilized and particularly instructive cuts freshly made would be rendered available.

5. It is conveniently located to the School of Mines. This would not only enable the prosecution of the work with less expense, but whatever of mineralogical or geological knowledge acquired would be of great service to the State in connection with the instruction of that institution.

HISTORY OF THE WORK.—Having completed our equipment for camping and sustenance and engaged a team and wagon, the party left Rapid City on the morning of May 10, 1895. The party consisted of the State Geologist, Professor J. E. Todd, of the State University, Frank C. Smith, Professor of Metallurgy and Mining Engineer of the School of Mines, Will Cumerihl, Charles Du Mours, Charles Gardner, Jesse Simmons and Frank Whitehead, students of the School of Mines. Our first camp was a little below Scott's Mill. From this point we made short excursions, usually in two parties until we had become acquainted with most of the rock exposures in that vicinity. May 14th we moved camp to McDonald's, a little above Florman's Tunnel.

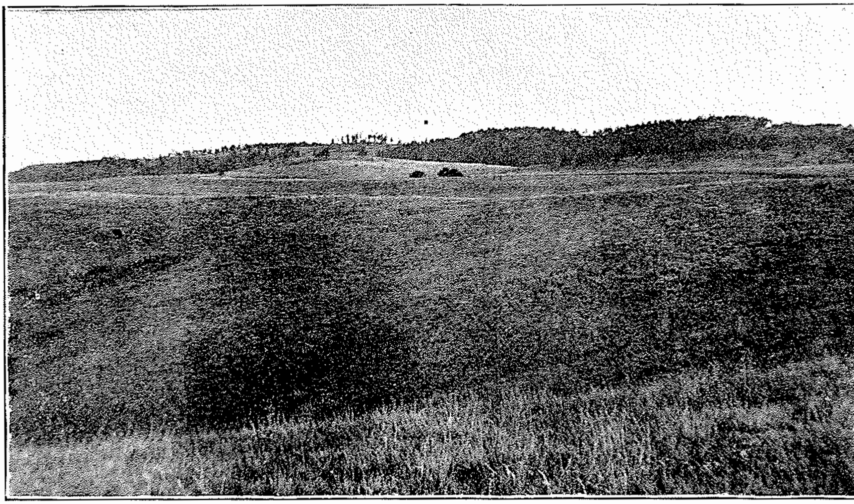
Having examined as fully as time would permit the position and character of the Paleozoic rocks, the State Geologist left the party in charge of Professor Smith who, being a mining engineer, was not only especially interested in, but particularly qualified for the remainder of the work. He continued the examination of the Algonkin slates along Rapid Creek as far as Rochford, where the close of the financial year arrested the work. A section representing the character and attitude of the rocks is shown in Plate II. The following is a detailed description of the same, beginning with the oldest and lowest rocks and giving them in the chronological order, or that of deposition. This follows regularly from the west to the east. So far as practicable, the sections follow the south side of Rapid Creek, omitting as far as may be the bends in that stream.

THE ALGONKIN SLATES.—These constitute the nucleus of the Black Hills and present a much more complicated structure than the other formations. Mr. Newton in his study of their structure speaks as follows: "Our examination brought to light no evidence of duplication of any portions of the Archean rock system. If the slates or schists were folded upon themselves and afterwards worn away so as to leave two or more parallel outcrops of the same beds, the folding must have been confined to the homogeneous soft beds; and the presumption is that no such folding took place within the area exposed in the Hills. The whole system of vertical beds with a width of about twenty-five miles is believed to retain its original relation of parts. It has not of course its original position, for the same great process of change which has produced its metamorphoric structure has turned it on edge, and either broken away or eroded away its upward continuation. But it is probable that the system presents the clays, shales and sandstones from which it was produced by metamorphosis in the same order in which they were originally deposited."

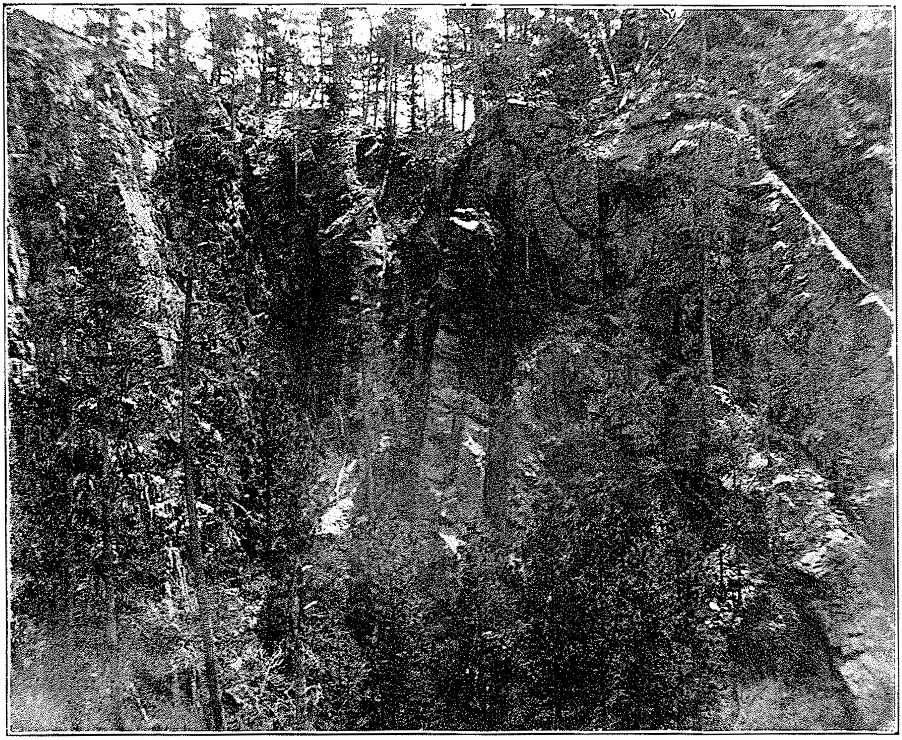
From an observation by Professor Jenney of unconformity, he divided them into a western or older series and an eastern or newer. In this conclusion he was followed by Dr. Carpenter and Professor Crosby. Professor C. H. Van Hise, who examined the Hills later (1890) and under more favorable circumstances, called attention to the fact that the dip of the slates was not so uniform as had previously been stated. He finds that "the prominent structures of the Black Hills which have heretofore been taken as bedding or strata are secondary structures produced by pressure, and as evidence of this is the fact that alternate bands of sediments of different characters are seen to cut across the prominent lamination of the rock." He calls attention to the fact that the dip of the schists and slates is away from the granite area. He also concludes that there is a gradation from the slates to the schists rather than an abrupt change. Therefore, he concludes that they cannot be divided into two series. This was the condition of knowledge concerning the slates when we began their study on Rapid Creek.

One reason why this location had been chosen was because of reported occurrence of quartzite beds alternating with the slates. It was hoped that this occurrence of strata, markedly different from one another, would assist in determining the distortion of rocks if any should be found. In this respect our expectations were more than realized. We found that the slates and alternating quartz strata were folded and faulted in a most complex and interesting manner. In the vicinity of McDonald's, about twelve miles west of Rapid City, folds of all attitudes and sizes could be traced in many cases without difficulty. In some cases an inclined fold running for half a mile or more with its upper member again thrown into secondary folds was found about a mile below Florman's Tunnel. In the sides of the gorge of Rapid Creek were similar anticlinal folds, rising to the height of sixty to seventy feet with a breadth of somewhat less. One is shown in Plate III, 2. These are formed around horizontal axes, but in some places the strata were folded around nearly vertical axes so that in weathering the quartzite sometimes appeared in quite regular spires, jutting from the side of the hill. The prevalent direction of the folds around horizontal axes instead of being approximately north and south was more commonly nearly east and west, in the region between Florman's Tunnel and Scott's Mill. Another point of interest is that the slates not infrequently instead of showing the high angle which Mr. Newton observed showed a dip less than twenty-five degrees toward the east. In the time allotted us the problem of unravelling these folds and showing their complete relation was clearly impossible. In the section as given little or no attempt to present these. Numerous notes were taken, recording the dip at various points and photographs of several of the most distinct were made.

COMPOSITION OF THE ALGONKIN ROCKS.—We have already referred to them as interstratified slates and quartzites. The slate for the most part is an impure argillite in some places quite micaceous, in others showing prevalence of hornblende. It seems not improbable that a regular series of strata may be eventually made out in the slates. But little progress was made in that direction during the work of the present season. About a mile and a half below Florman's Tunnel Rapid Creek cuts through an exceedingly hard and tough hornblendic rock with quite regular joints and fine grained structure. It resembles very much columnar trap, but we found no evidence of a dike. It seemed rather a development of a regular stratum of the Algonkin formations. Layers of quartzite occur of all thicknesses from a few inches to several rods. Some of them seem to be of no great extent but of lenticular form, but often one of the thicker strata may be traces for several miles. The quartzite strata are usually of a gray color, sometimes quite light, but more frequently dark. No traces of fossils were found in them. Veins of white quartz occasionally occur cutting across both the slate and the quartzite. These seem not to be regular



1. The High Terrace 450 feet above Rapid Creek.



2. Folded Strata on Rapid Creek, above Scott's Mill.

fissure veins, but rather veins of segregation. They are of very irregular form. No distinct traces were found of limestone or marble, although cases were reported from the vicinity where a gray marble blotched with white is found with a thickness of 200 to 250 feet. No dikes of granite or other eruptive rock were found.

THE RELATION OF LAMINATION TO STRATIFICATION.—In most cases these seem to correspond in direction. Of course where slate and quartz are interstratified these may be easily traced. But in areas of slate alone, it is often difficult or impossible to determine. Upon a high knob southwest of the head of the flume above Florman's Tunnel, the following notes of stratification and lamination were made: The strike of the lamination of the slate is north 85 degrees west, dipping about 61 degrees to the north; while the strike of the stratification is north 55 degrees west, with the dip 63½ degrees northeast. The lamination is nearly always, except in distinct folds, dipping from 60 degrees to vertical. It is believed that a patient and careful study of the Rapid Creek section will be most instructive concerning the succession and the disturbance of the Algonkin rocks in the Black Hills.

THE CAMBRIAN.—Concerning this our study in the main corroborates that of Mr. Newton. The only representative of this age is the Potsdam sandstone. We found but one distinct exposure of the junction of the Potsdam with the slate, and that was about two and a half miles below Florman's Tunnel. We found the thickness of the Potsdam along Rapid Creek to be between 200 and 250 feet. The succession of strata as we saw them from exposures about a mile and a half above Scott's Mill or in the vicinity of the first cut through the slate along the Dakota & Wyoming Railroad are as follows:

SECTION OF POTSDAM.

7. Thin-bedded rusty sandstone, sometimes absent, 12 to 15 feet.

6. Heavy-bedded, irregular, rusty-brown sandstone with frequent oblique lamination in different directions, 40 to 50 feet.

5. Red, thin-bedded sandstone, interbedded with shale, showing frequent fucoidal casts, thickness, 50 to 60 feet.

4. Dark shales with a few thin layers of limestone, conglomerate toward the top, the pebbles light green with pink cement, 55 to 60 feet.

3. Thin calcareous layers interbedded with some shales and sandstone. Layers containing Glauconite near the top, below frequent fossils of Obolella and Lingulepis. 35 to 40 feet.

2. Coarse, rusty, heavy-bedded sandstone, 50 feet.

1. A dark rusty, conglomerate, weathering in large blocks, and resting on the slate, 8 to 12 feet.

Total thickness, 240 to 290 feet.

The thickness of the basal conglomerate was not clearly determined as the slope north of the flume dam at McDonald's was strewn for several rods with the large blocks. Some of the layers of Nos. 5 and 6 are fine grained and abound in iron, perhaps sufficiently so to serve as ore. The dip of the Potsdam as determined near the slate cut was 5 degrees due northeast. In Dark Canon it was found in one place 10 degrees east. It seems probable that the basal conglomerate is lacking at some points, at least sections apparently favorable for its appearance do not show it. Although the upper strata of the Potsdam seem to be conformable with the overlying Carboniferous, there is little doubt that there is some erosion, rendering the surface of the Potsdam in different localities considerably different. No clear evidence of this sort was found along Rapid Creek, but the occurrence of No. 7, a thin bedded sandstone, in some places, while it is absent in others, may be considered as an illustration of this fact.

THE CARBONIFEROUS.—Though careful search was made for Silurian rocks of the formation found at Deadwood, no trace of them could be found.

General Section of Carboniferous Rocks along Rapid Creek.

5. Gray and yellow sandstones, coarse above, with a band of red brecciated sandstone about thirty-six feet below the top. The upper portion more jointed, with vertical and oblique seams. Thickness, 90 to 100 feet.

4. A red brecciated sandstone, apparently thickening to the east, 30 to 40 feet in thickness.

3. Mostly thin-bedded sandstones and sand, red, yellow and gray, with thin beds of limestone, usually irregular, interstratified below. The sands are freqently seamed with calcite and show small cavities lined with calcite crystals, 245 feet.

2. A massive thick-bedded limestone, seamed from top to bottom, generally so as to form imposing cliffs, the upper 40 to 50 feet brecciated, the whole with calcite geodes, and the upper

half often showing considerable caverns. Chert concretions, quite regularly arranged in the upper part; some strata quite sandy. The upper portion, besides showing rounded cavities, exhibits angular openings in certain strata as though a portion of the brecciated fragments had been dissolved out, color uniformly white, light gray, or cream color. Fossils found: Productus, Spirifera, Syringopora, Crinoids, Euomphalus, Cyathophyloid Coral, 180 to 200 feet.

1. Shaly limestone, thin-bedded argillaceous, red to pink, weathering with rounded corners. Syringopora corals frequent from top to bottom, with the species smaller below. Crinoidal joints very abundant in some of the lower layers, the horn-shaped coral very common. Spirifera not uncommon and a Strephomena-like shell. The upper ten feet with calcite geodes, 30 to 35 feet.

Total, 575 to 620 feet.

Number one usually forms a slope from the top of the Potsdam sandstone to the base of the imposing cliffs which are formed by No. 2. Numbers 3 and 4 usually constitute a slope with frequent ledges. Number 5 by its coloring and method of weathering frequently resembles the purple limestone above it. No fossils were found in Nos. 3, 4 and 5. In comparing this with Newton's division of the Carboniferous, No. 1 corresponds to his "shaly limestone," No. 2 to his "gray and silicious limestones." Nos. 3, 4 and 5 to his alternating series. No traces of carbonaceous shales were found or anything to indicate the vicinity of coal deposits. The upper portion of No. 2 is frequently so seamed that when undermined by the stream immense blocks forty or fifty feet in thickness either overhang the stream many feet or may occasionally break off en masse.

THE TRIASSIC.—This, as elsewhere, is represented by three quite distinct portions, namely:

Number 3. Red sandy clay, containing masses of gypsum, estimated 150 feet thick.

Number 2. Purple limestone curiously flexed into dome-like elevations, very uniform in structure, though in places showing a shaly character and usually seamed from top to bottom. Thickness, 45 to 50 feet.

Number 1. Brick-red sandy or marly clay, similar to No. 3, 55 to 60 feet.

Total, 250 to 260 feet.

Number 1 seems thinner along this section than is generally found. There was no opportunity of measuring carefully the thickness of No. 3. Number 2, the purple limestone, has by previous observers been pronounced non-fossiliferous; but upon the cliff north of Cleghorn's, numerous specimens were found of a small bivalved shell rather imperfectly preserved, which was pronounced by Mr. T. W. Stanton, of the United States Geological Survey, to be "probably a species of Astarte." These were found in the shaly stratum about ten feet above the base.

The section which Newton gives along Rapid Creek shows a dome-shaped flexure of the purple limestone in the Red valley. That feature found a mile or more north of the stream is local and, therefore, does not appear upon the section given by us. We subjoin the section of Mr. Newton for this region which is more complete than we have observed:

"6. Clay, red, with some gypsum, — feet.

5. Gypsum, white, 8 feet.

4. Clay, with several seams of gypsum near the base, 40 feet.

3. Gypsum, white, 8 feet.

2. Clay, red, with some gypsum, 75 to 100 feet.

1. Limestone, purple, 25 feet." *

THE JURASSIC.—This is not well exposed nor fully represented in this section. Professor Carpenter called attention to its unconformity with the overlying Cretaceous near the gap. Its junction with the Triassic we have not observed. Mr. Newton seems to have extended the Jurassic up to a heavy sandstone stratum just north of the gap. He says: "At the pass of Rapid Creek through the foot hills, the cliffs are capped by a heavy bed of the Dakota sandstone about twenty-five feet thick, stained deeply red, and containing many ferruginous masses. Below this sandstone are about 200 feet of poorly exposed Jurassic beds, resting upon the red gypsiferous clays of the red beds. The Jurassic beds consist in their upper part of shaly and soft sandstones with clays or marls, and have below a greater thickening of greenish, drab and yellow marls or clays with some streaks of deep red, and a snowy-white stratum of very soft argillaceous sandstone. This sandstone appears to be some eighty or ninety feet in thickness, and be

* Geology of the Back Hills, p. 143.

traced by its vivid whiteness several miles along the foot-hills. It weathers readily somewhat like a clay, and is probably a local variation of some of the argillo-arenaceous beds of the formation." In this section he has included under the Jurassic numbers 1, 2 and 3 of the Dakota formation as we have given it. No characteristic fossils have been observed in the strata, but the occurrence of fossilized wood of a Carboniferous character and leaf marks in the fire clay point to the Cretaceous rather than the Jurassic. In our drawing of the section we have passed over a portion where the Jurassic is but little exposed. Hence we have supplied inferentially from observations made north of Rapid Creek Gap and near Tilford. With this qualification we give the general section as follows:

3. Gray and greenish shaly clay, usually imperfectly exposed, 55 to 60 feet.

2. Fine-grained, massive argillaceous sandstone, weathering with polygonal cracks and containing large round concretions. Sometimes it is of a light yellow color, and often of a bluish tint, 80 to 90 feet.

1. Light colored clays, shales and impure limestone, the latter principally represented by a stratum 3 or 4 feet in thickness, containing fossils of Belemnites and small oyster shells, 50 to 75 feet.

Total, 185 to 225 feet.

No. 3 seems to be absent north of the Gap, but south of the Gap it probably constitutes a part of the long slope above the central sandstone. It seems evident from a comparison of the different sections about the Hills that the Jurassic varies greatly not only in composition, but in its thickness. The latter probably is mainly due to erosion before or during the deposition of the Dakota sandstone.

THE DAKOTA FORMATION.—This is not very well exposed along the line of our section. Hence we have supplemented from observations made further north with considerable uncertainty, especially concerning the upper members. We give the section as follows:

Section of the Dakota Formation.

6. Sandstones quite compact and forming ridges under the influence of erosion, 15 to 25 feet.

5. Clays and shales with one to three unimportant strata of thin sandstone, 150 to 200 feet.

4. Heavy, coarse red and rusty sandstone, forming cliffs, 25 to 30 feet.

3. Shaly sandstone with a stratum of carbonaceous shale from 10 to 12 feet thick.

2. A fire clay thickening to the south, showing impressions of leaves in some places, and south of the Gap apparently 40 or 50 feet in thickness, though this may be due to other material introduced between upper and lower members; 20 to 50 feet.

1. Thin-bedded and ripple marked red sandstone, quite compact and forming cliffs above, also frequently thickly strewn with petrified wood in its upper portion, 100 to 150 feet. The sandstone members of the Dakota formation usually show more or less coarse material, especially below, and frequently oblique lamination. This formation is the main cause of the outer rim or foot hills of the Black Hills. A characteristic view of it is shown in Plate IV.

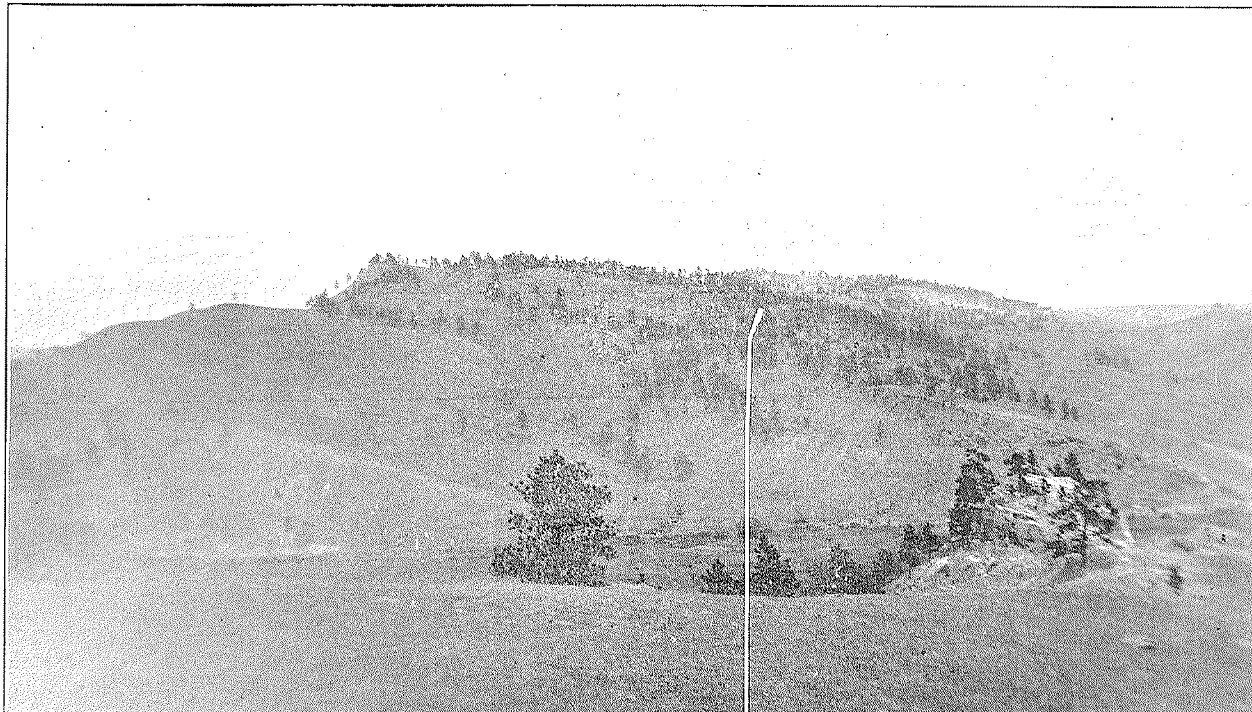
COLORADO FORMATION.—Lying upon the sandstone of No. 6 and resembling in character the clays of No. 5 are the clays of the Colorado group of undetermined thickness. The calcareous portion corresponding to the Niobrara chalkstone in the eastern part of the State is not developed in the vicinity of Rapid Creek except in the form of light colored calcareous clays scarcely consolidated. The before mentioned drab colored clays of the Colorado formation form the main body of the high terrace lying southeast of Rapid City, upon which the cemetery is located.

Several fine specimens of fossil cycads, resembling those which have attracted wide attention from near Minnekehta, have been found near Rapid City, and are now at the School of Mines.

LATER FORMATIONS.—No traces of later formations have been found along the line of this section, except possibly of the Pliocene Age which have not been clearly differentiated from those of the Quaternary or Pleistocene epoch. The latter is mainly represented by erosion on a grand scale with the formation of terraces thickly covered with fragments of the harder portions of the Archean rocks from the central Hills.

TERRACES.—There are three or four well defined terraces, some of them of a very imposing character. The highest of these, and doubtless the first in age, is of great extent and forms

Plate IV.



Rapid Creek gap through the ridge of Dakota Sandstone. This formation supplies the principal artesian wells of the state and this illustrates where and how the water may enter.

one of the conspicuous features of the Black Hills. When viewed from the summit of Dakota Ridge, it appears as a broad shelf cut into the main body of the Hills on both sides of Rapid Creek. A view is shown in Plate III, 1, of its general surface in the vicinity south of Scott's Mill. It is there from 430 to 450 feet, above the level of Rapid Creek. See Plate II, M. It slopes rapidly to the east. The plane of its upper surface would rise higher than most of the points in the outer foot-hills. South of Cleghorn's it is still about 430 to 450 feet above Rapid Creek. We were unable to recognize distinct traces of it in the outer rim of the hills, but we would connect it with some of the higher hills or buttes along the divides between streams east of the hills. It seems not improbable that it marks an epoch corresponding to the deposition of pebbles and boulders upon the summit of the Tertiary beds as far east as White River: or in other words, corresponding to the summit level of buttes in the Bad Lands, Sheep Mountain, Cedar Mountain, the Great Wall, and other conspicuous points. Its surface near Rapid Creek is gently undulating, is covered with loam and supports a rich growth of prairie grass. Its contrast with the surrounding pine-clad hills is very marked. Its subsoil and upper portion consists of a mixture of clay and boulders or pebbles, reminding one of a glacial deposit, but no striation of pebbles or rocks has been observed, and the usual features of glaciated regions are lacking. This deposit may be found from 10 to 25 feet in thickness.

The next terrace, Plate II, N, also quite conspicuous at our first camp, was found from 300 to 315 feet over Rapid Creek, and in some places was several score of yards in width. The slope between the two terraces is not always sharply defined, but this may be ascribed to the varied character of the rocks and the results of later erosion. Opposite Cleghorn's it is about 270 feet above the stream, and very probably the gravel marked shoulder north of the gap, 144 feet above the stream, and the extensively developed table south and east of Rapid City, 135 to 150 feet above the depot, are portions of this same terrace; so also the well developed high terrace which may be seen almost continuously down the north side of Rapid Creek to the Cheyenne.

A third terrace which near our first camp was 90 to 100 feet above Rapid Creek and which is represented at several other points between that and the Gap may correspond to a terrace near the Gap, 25 to 30 feet above the stream. There seem also to have been other intercalated terraces which show locally along the creek between these two, but which have not been carefully studied. They are thickly strewn with the pebbles and boulder formed of the more durable rocks of the Archean neuclus. The materials are usually coarser below than on the top, and except where removed by erosion, there is a considerable stratum of yellow loam underneath the thin soil. The lower terraces have usually finer material than the higher, indicating less power within the stream. This probably was due as much to the volume of water as to the slope.

ECONOMIC NOTES.

Our chief attention, during the brief time spent in the work was given to the arrangement and general character of the strata, rather than their economic values. We will mention, therefore, only a few of the more obvious economic results.

Professor Smith has not, hitherto, been able to work out the results of his study of the schists; hence we are not prepared to speak very intelligently concerning the occurrence of the precious metals. Gold is found in placers along Rapid Creek at many points, both in the alluvium along the present stream and in the higher terraces. But the quantity found has usually been disappointing. The veins found in the schists have also been found not very rich. This is particularly true of the portion studied by our party.

Iron ore occurs in the base of the Potsdam but not of any considerable value.

A vein of asbestos is reported and coarse specimens have been shown from near Rochford but the locality has not been critically examined.

The deposits of fire clay in the Dakota near Rapid City are extensive, easily accessible and of excellent quality, with plenty of water at hand. Other clays in the Red Valley have been profitably used for brick.

No traces of coal were found in the Carboniferous series in the region studied. The Carboniferous in the Black Hills, as in the west generally, is entirely a misnomer.

The Dakota formation bears a thin vein of lignite above the fire-clay. This was exploited a few years ago and found not thick enough to be worked. At present the former exposure is buried. It seems very improbable that it will be found thick enough anywhere on the east side of the Hills to have any value, but it can hardly be said to be impossible.

Gypsum of a mottled gray and white colors is found in large irregular masses in the Red Valley. An attempt has not been made to estimate their size or location definitely.

The Purple limestone is quite pure carbonate of lime and would doubtless make excellent lime.

The Carboniferous limestones are generally more magnesian.

Excellent building stone of wide range of color, quality and durability may be obtained from the Potsdam, Carboniferous and Dakota formations.

The calcareous conglomerate in the Potsdam, showing delicate green and red tints, may sometime be found valuable for small ornamental pieces. It cannot be obtained, however, in large quantities, nor in very large pieces.

The relation of Dakota Sandstone to Rapid Creek, as well as to other streams in the Black Hills, is especially interesting in connection with our Artesian resources. This is the great water-bearing formation, in the artesian area which covers perhaps more than half of our State. It is probable that some of the water enters at the Gap, where the stream passes over upturned edges of the sandstone, but the amount which does so directly would seem necessarily small, when we consider that the sandstone is exposed for only a few rods and the stream is but a few feet wide. However, we should not forget a much larger surface of the rock in contact with porous alluvial formations saturated with water. From the rate of increase of pressure in artesian wells toward the west, it seems not improbable that flowing wells may be obtained from the Dakota along Rapid Creek a few miles east of the gap by boring a few hundred feet, as has been done along the Belle Fourche.

Moreover, we have reason to believe that in the western part of the State water may also be obtained from the Sandstones of the Carboniferous and from the Potsdam by going deep enough. It is probable that the great springs escaping from the Purple limestone at several points in the Black Hills come from these sources. In fact the water might be struck in that limestone, though it may come into from the lower formations by faults. The Purple limestone lying as it does between beds of red clay doubtless acts as a conduit. There would be, however, less certainty of striking water in it, than in a porous sandstone because the water would be confined to fissures mainly. The depths to the different strata may be roughly estimated by taking their thicknesses from the section and allowing for the effects of dip.

Allusion has been made to springs from the Purple limestone. I am not aware of any such very near our section. Copious springs from beds of gravel near the level of Rapid Creek at Cleghorn's are quite famous. Their source has been considered quite mysterious. The class to which they belong is quite widely represented about the Hills in the valleys of the different streams. The more natural and probably the true explanation of them is that they are merely the reappearance of water which has entered the gravel beds from the main stream or from some of the tributary gulches, at a higher level. It seems probable from topographic relations that the Cleghorn springs are supplied largely from Wild Irishman's gulch. The waters are very clear, palatable and wholesome, and were once talked of as a supply for Rapid City.

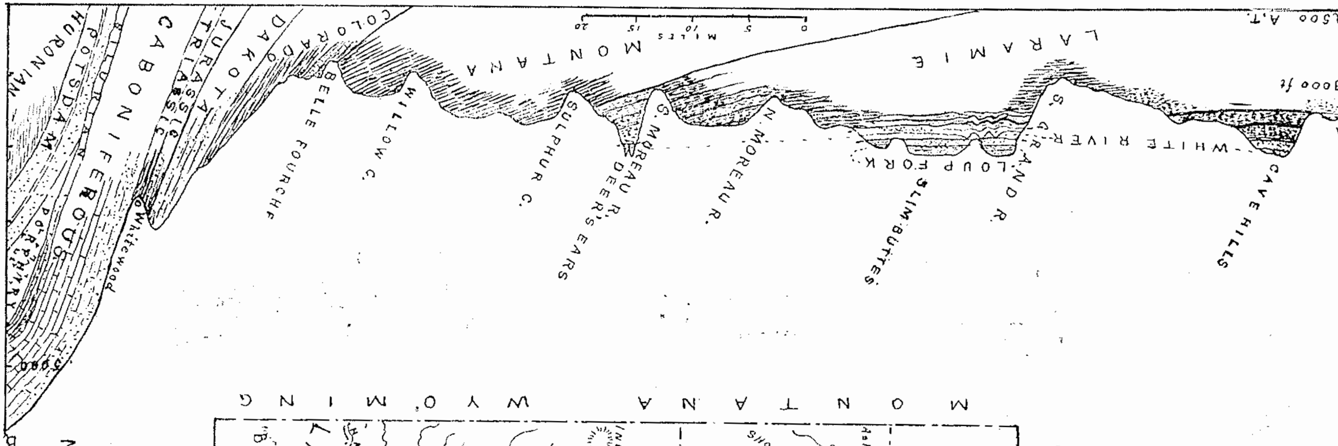
Rapid Creek from its large drainage area and its slope furnishes great water power, and may become the location of great manufacturing interests.

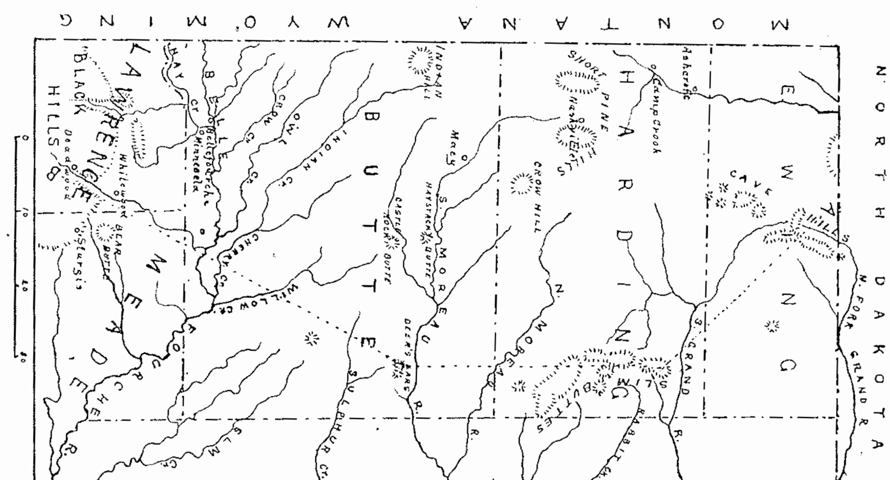
Canyon Lake is artificially formed by a dam eighteen or twenty feet in height. Though originally planned for use in the development of a projected western addition to Rapid City, both for power and water supply, it is now mainly a pleasure resort and feeder of a few irrigation ditches.

The value of Rapid Creek as an irrigation supply has long been recognized and grand schemes for its utilization have been projected and partially developed in years past, but though probably well founded, they failed for lack of patronage.

The ultimate development of the portion of Rapid Creek considered in this paper, will, doubtless, be in the lines of manufactures and intensive agriculture. The manufactures in part may be separation of the precious metals found about its upper sources and in other portions of the Hills less abundantly supplied with water.

J. E. TODD.





MAP & SECTION

OF

NORTHWESTERN SOUTH DAKOTA

J. E. TODD

1896

A Reconnoisance Into Northwestern South Dakota.

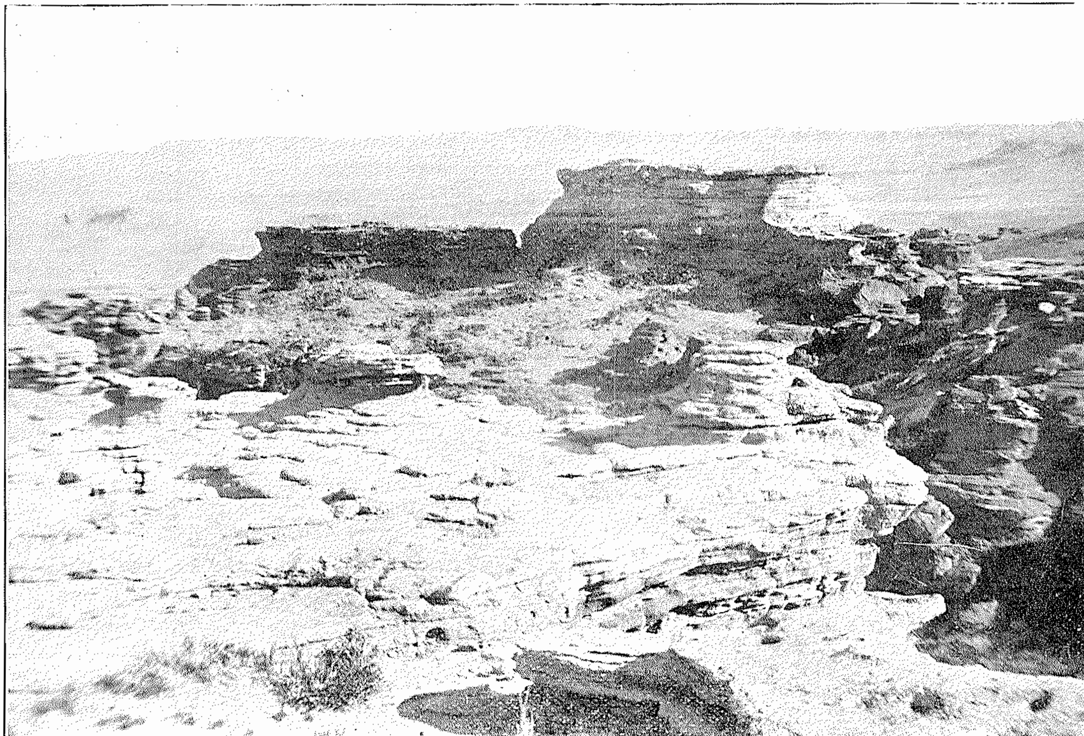
ITS AIM.—The object of this expedition was to explore a portion of our State almost entirely unknown geologically. Professor N. H. Winchell, Geologist for the Custer expedition of 1874, hastily visited several of the more conspicuous points in the region and reported the existence of beds of lignite of considerable thickness. It was largely with the purpose of ascertaining the nature of these deposits that the present trip was undertaken.

ITINERARY.—Having engaged a camping outfit with team and driver, Mr. Chas. Whitman, I left Rapid City, May 21, 1895. We went by a direct route past Sturgis and Whitewood to Belle Fourche. From this point we made an excursion of two or three days to examine the Hay Creek coal fields to ascertain their age and to accumulate data for comparison with the field to be visited. We proceeded along the stage route by way of Macy, Nashville and Camp Creek to Ashcroft. From thence we followed a trail east-northeast to one of the older ranches on the west side of the North Cave Hills owned by Mr. G. M. Dell. From that as a central point we made short trips occupying a week. We then passed around north of the North Cave Hills and down the east side to Riley's ranch, and from there we took a trail to and down the north fork of Grand River to the "E. O." Ranch, thence south to the south fork of Grand River, thence west to Turkey Track Ranch, thence north again to the North Cave Hills. Having completed so far as time would allow the examination of the North Cave Hills, we proceeded to the Slim Buttes, examined the northern end both on the east and the west sides and also in the vicinity of "E 6" Gap, thence down the west side past Calbrick's ranch to the second gap, thence to the "J. B." horse ranch and south along the east side of the Buttes to the Mountain Sheep Butte and the North Fork of the Moreau River, thence to its junction with the South Fork, then by the usual trail past Deer's Ears and Owl Butte to the mouth of Horse Creek and up Whitewood Creek to Whitewood.

Having a few days to spare, we took a trip from Whitewood to Deadwood, thence by the old trail to Sturgis back to Rapid City, arriving there July 30th. Many notes were taken of sections of strata, especially in the Cave Hills and Slim Buttes, and much information concerning the topography, soil and geology of the country was accumulated. The space alotted for this report does not permit a full presentation of these data, and they will be largely kept for future reference of the survey. We simply endeavor to present the more significant and characteristic sections and give the prominent features in the form of a general section across the country from the Cave Hills through Slim Buttes and Deer's Ears to Whitewood.

TOPOGRAPHIC FEATURES.—The course to and from Whitewood and to Hay Creek lies wholly within the boundaries of the Black Hills proper and is confined mainly to the Red Valley and the Dakota Ridge, which forms the rim of the Hills. In general, the rest of the region may be spoken of as a high table land constituting the summit of the divide between the Little Missouri and the Moreau and Grand Rivers. Most of the surface is quite uneven, showing the ordinary effects of erosion. The region a few miles away from the streams is only gently undulating with the valleys from twenty to fifty feet below the summits of the intervening hills. The valleys of the main streams, particularly the Little Missouri and the north and south branches of both the Grand and Moreau Rivers, have cut below the general level of the plain to the depth of 150 to 250 feet. So much for the general ground work, upon which are elevated to a considerably higher level the more prominent hills or buttes which are very conspicuous features of this region. These rise from 250 to 350 feet above the average upland level, or 500 to 600 feet above the larger streams. The sides of these buttes are usually very abrupt, and larger ones, which are flat topped and often of considerable extent, are surrounded by lower hills of rougher character rarely showing any flat top. A list of the more prominent buttes may be given as follows:

In the extreme northwestern corner of the State is the northern end of a ridge called the Long Pine Hills, west of the Little Missouri.



The east side of the Cave Hills, looking south from McVey's.

Close upon the north line of the State are the Pommes Blanches Hills. The latter do not show conspicuously the flat top.

Next south are the Cave Hills comprising two main divisions. The North Cave Hills have a length north and south of about twelve miles and a breadth from a half to one and a half miles, the outline being much cut up into deep recesses and striking promontories. Plate VI exhibits these features. The South Cave Hills, lying southwest of the North, are one to two miles in length and include two or three detached or nearly detached members. South of these are also several conspicuous peaks, extending along the divide toward the Short Pine Hills.

The Short Pine Hills include two ranges lying nearly parallel, running north and south, which are from four to six miles in length. They are flat topped and the Pleasant Valley, so named by General Custer, lies between them. Nashville is now situated in that valley.

The Slim Buttes form an L-shaped ridge extending for twenty-five or thirty miles with a breadth of from one-half to two or three miles. The longer portion of the L lies north and south near the east side of Harding County, and the shorter portion extends east of south between the head waters of Rabbit and Antelope Creeks.

Mountain Sheep Butte is a detached irregular clay ridge, extending the southern point of Slim Buttes.

Hay Stack Butte and Castle Rock Butte are majestic landmarks lying on opposite sides of a branch of the South Fork of the Moreau River.

East of the latter about fifteen miles is Deer's Ears, so named from the sharp peaks of equal height which lie east and west of one another and from their form suggest the name.

Owl Butte is a less prominent butte of quite irregular form along the head of Sulphur Creek.

Another conspicuous butte lies fifteen or more miles west of Castle Rock. Its sides are not well defined, but it rises as a high knot of hills about the head waters of Indian Creek.

The divide between the two forks of Grand River extending east of the Cave Hills is more than usually rough and occupied by prominent peaks. Some of them have definite names as Lodge Butte and Eagle Nest Hills, but they are not higher or more prominent than many others.

Many of these buttes, more definitely the Short Pine Hills and Slim Buttes, show flat tops covered with luxuriant grass and presenting features reminding one strongly of rich bottom lands. Their flat tops evidently lie on very nearly the same level and are apparently the remains of the original surface of ancient Lacustrine plain of Tertiary age. They are mostly covered with a rich soil and luxuriant grass with sometimes shallow basins containing water in the rainy season. In the case of Cave Hills, while the flat top is presented, the deep loamy soil is almost absent; hard sandstone being usually prominent. The large hills are all of them more or less supplied with timber, the red pine growing abundantly in the ravines which dissect their sides and showing above the surface of the summit plain.

ALTITUDES.—We are unable to give altitudes with much accuracy as no railroad surveys have been projected through this region. From a series of barometric readings at Ashcroft, it has been estimated to be about the altitude of Rapid City, or about 3200 feet above the sea. This marks the level of the bottom lands of the Little Missouri at that latitude. From the United States Geological Survey we learn that the summit of the Rabbit Butte is 3000 feet. We therefore estimate that the average upland level of the divide is about 3400 feet, while the level of the before mentioned Lacustrian plain is probably 3600 to 3800 feet near the Little Missouri and declines gently toward the east, Rabbit Butte not reaching to that level.

STREAMS.—We need not occupy space in enumerating all of the streams of the region, but simply speak in general concerning the depth and breadth of valleys. The Little Missouri and Belle Fourche have valleys from one to two miles in width, and considerable bottom land a little above the stream with one or two high terraces of greater breadth. The streams forming head waters of Cherry Creek and the Moreau and also the South Fork of the Grand River are usually without wide valleys. The streams are usually clayey, the sides of the valleys are quite sloping and not sharply defined. They are none of them very copious in the dry season, but are subject to great floods. For this reason the smaller streams are usually broken up into water holes which retain much of the water after the streams have ceased to flow. Springs are rare over the region occupied by the Colorado and Montana formations, but in the Laramie they are not infrequent, especially about the large hills like the Cave Hills and Slim Buttes. Along the larger streams cottonwoods are a prevalent tree, sometimes occurring in considerable groves. They are often of considerable diameter, but usually low and scraggy. Ash, box-alder and elm are also frequently present.

GEOLOGIC FEATURES.—The geological formations met with in this expedition outside of the Black Hills are only those belonging to the Cretaceous and Tertiary. The epochs represented of the Cretaceous were the Dakota, Colorado, Montana and Laramie. Of the Tertiary so far as yet determined, the White River and Loup Fork groups are of the Miocene. The Pliocene and Quarternary are only represented by the terraces of the region.

THE DAKOTA FORMATION.—This is the oldest of the Cretaceous formations met with. It forms the outer rim of the Black Hills as has been frequently stated, and we need say little concerning it here except to call attention to the fact that instead of presenting an evenly curved ridge around the Hills as has been represented by Mr. Newton in his report, it is thrown by subordinate folds into scalloped outline. One of these subordinate folds with its axis dipping to the north extends north from Whitewood, and another appears north of Minnesela. And we might add here, although it is beyond the limits of our field, that a considerable fault was noticed running north and south across Hay Creek, above the forks. The Hay Creek Coal stratum apparently corresponds to the thin layer of coal north of Whitewood, discovered even before the publication of Mr. Newton's report.

THE COLORADO FORMATION.—This includes the dark clays overlying the Dakota and the light colored calcareous shales higher up. The latter are not well defined, but are found in some of the higher terraces along the Belle Fourche as near the mouth of Whitewood Creek and along the divide between Crow Creek and Owl Creek. The dip is a small angle toward the northeast.

THE MONTANA FORMATION.—This is only distinctly represented by the Fort Pierre. We were unable to identify any of the sand layers in the base of the buttes with the typical Fox Hills, although it is possible that some of the strata which we have included under the Laramie belong to that stage. There was nowhere found that rich deposit of fossils which characterized the Fox Hills formation near the Missouri River. The Fort Pierre clay was found to extend much further north than was indicated on the map published in Bulletin No. 1, of the Survey. It extends as far north as the base of the Short Pine Hills and also to Sulphur Creek and over most of the region as far north as the north branch of the Moreau, with the exception of the more prominent buttes which are outliers both of the Laramie and the Tertiary. This formation presents its usual character of gumbo clays with several horizons of large biscuit-shaped concretions. The latter are largely non-fossiliferous, but we noticed toward the base of the formation along Willow Creek the frequent occurrence of Helicoceras and occasionally of Reptilian vertebra; also between Willow and Cherry Creeks "Tepee Buttes," which owe their existence apparently to boulder-like masses thickly filled with shells of a species of Lucina, illustrating well the facts presented by Gilbert in his description of Tepee Buttes. (Bulletin G. S. A. Vol. VI.)

THE LARAMIE FORMATION.—This is both the most prominent formation of the region visited and that which furnishes facts of greatest interest. It occupies the most of Ewing, Martin and much of Harding county. Perhaps its most complete representation is found between the Cave Hills and the Little Missouri. Because of this fact we shall proceed to give representative sections not only of the Cave Hills, as the fullest rep. resentation of the formation, but also of the Slim Buttes which exhibit this formation with the overlying Tertiary. After a presentation of these sections we may infer some of the general facts concerning the whole.

Before giving these we would state that since we had no better plane of reference because of the smallness of the stream's and the absence of railroad surveys, we have chosen the original Lacustrine level as a datum plane.

A Section About Two Miles North of Dells.

Top about 125 feet below the top of Cave Hills.

	Feet
19. Yellow Sandstone, probably the lower portion of the capping sandstone of the Cave Hills	6
18. Light drab, sandy clay	7
17. Course, massive yellow sandstone	2½
16. Thin yellow and drab rusty sandstone with light drab interstratification	4
15. Yellow sandy loam with some dark layers	20

14. Drab colored silt with limonite concretions above, passing below into laminated drab shaly clay with large selenite crystals toward the top	17
13. Lignite	1½
12. Yellow and drab silt	7
11. Laminated silt	3
10. Yellow loess-like silt with reddish iron concretions	20
9. Drab clay with selenite crystals	20
8. Lignite	1
7. Drab loess-like silt	2
6. Much cracked semi-concretionary limestone	½
5. Drab clay	8
4. Lignite	2⅓
3. Slope, probably silt	15
2. Carbonaceous streak	1½
1. Slope, with stratum of sandstone concretions below	35
Total	173

Section Northeast of Campbell's, About a Mile East of the Last.

	Feet
17. Fine grained yellow quartz, resembling buhrstone, with casts of plant stems	2
16. Laminated and whitish sandstone, dipping east	12
15. A white plastic clay with green-sand grains	5
14. Sandstone, hard and even above, below soft. This comprises the cap stratum of the Cave Hills. The preceding numbers are in a hill rising above the general level	90
13. Yellow sand shading down into clay	12
12. Drab sandy clay and silt	20
11. Laminated clay	7
10. Yellow loess-like silt, with reddish iron concretions	20
9. Drab clay with selenite crystals	20
8. Lignite	1
7. Drab, loess-like silt	2
6. Much cracked, semi-concretionary limestone	½
5. Drab clay	8
4. Lignite	2½
3. Slope probably silt	15
2. Carbonaceous streak	1½
1. Slope with stratum of sandstone concretions below	35
Total	254

Toward the north the capping sandstone seems to be thinner. Back of Curlis's, extending to the level of the house, we have the upper portion of the following section which we have continued still lower by the beds exposed down the valley to the north.

Section at Curlis's and North.

Top estimated to be about 75 feet below the average top of Cave Hills.

		Feet
9.	Rusty sandstone with some layers having leaf impressions...	40
8.	Slope, mostly clay and loam	50
7.	Lignite exposed in a spring	2
6.	Slope, probably clay	8
5.	Lignite	4
4.	Yellow clay with a band of ferruginous concretions	6
3.	Shaly lignite	1⅓
2.	Drab clay with some calcareous concretions	5
1.	Lignite	2
	Total	118

Further north these beds of lignite have been burned out and left slag formations and brick red shale.

Section near McVey's, 3 or 4 Miles North of Ludlow's Cave.

Top equal the top of Cave Hills.

		Feet
11.	Sandstone usually yellowish and cavernous, firmer below	63
10.	Sand and yellow loam	25
9.	Slope, probably mostly clay	50
8,	Stratum of sand containing laminated calcareous concretions with many leaves and plants	2
7.	Slope, partly if not all loam	20
6.	Lignite and a copious spring	2
5.	Drab plastic clay	1½
4.	Shaly clay	2½
3.	Mostly clay slope	40
2.	Lignite corresponding to that prominent in the Red Buttes northeast	4⅔
1.	Clay slope	10
	Total	225

Section at Riley's.

This section begins with the high detached tables on or near Section 23, higher than the average top-level of the Cave Hills, and is continued downward along the ravine northeast.

		Feet
24.	Hard rusty sandstone with scattered boulders of buhrstone on top and local beds of clay and sand	60 to 70
23.	Drab plastic clay with many yellow iron concretions	6
22.	Soft sandstone yellow above and gray below	45
21.	Plastic clay shading into sandy clay below	45
20.	Gray and drab plastic clay with a layer of rusty concretions at the bottom	40
19.	Mostly plastic clay	30
18.	Lignite, impure but well defined	1
17.	Black shaly clay, including lignite	5
16.	Cream colored clay	6
15.	Black shale with two layers of lignite	1

14. Dark gray plastic clay	5
13. Cream colored silt	2
12. Shaly sandstone, thickening toward the northeast	1
11. Light yellow sand passing into loam below	5
10. Impure lignite	1
9. Slope, burnt fragments	5
8. Yellow loam	12
7. Good lignite	1½
6. Light colored plastic clay	8
5. Dark plastic clay with ferruginous concretions and a 14-inch layer of hard even sandstone on top	30 to 40
4. Slope	20
3. Cream colored sandstone with large log-like concretions toward the top	12
2. Lignite of excellent quality near Riley's, and lower down the stream exposed to greater thickness	7
1. Light colored fire clay	6
Total	355 to 375

This thick layer of lignite was traced for several miles to the east and north by the red-topped buttes and slag-like boulders, and probably corresponds to a thick vein found along the north fork of Grand River near the north line of the State. At the "E. O." Ranch possibly this same stratum appears with varying thickness from one to three or four feet in thickness with a thinner one a little above.

Section near Ludlow's Cave.

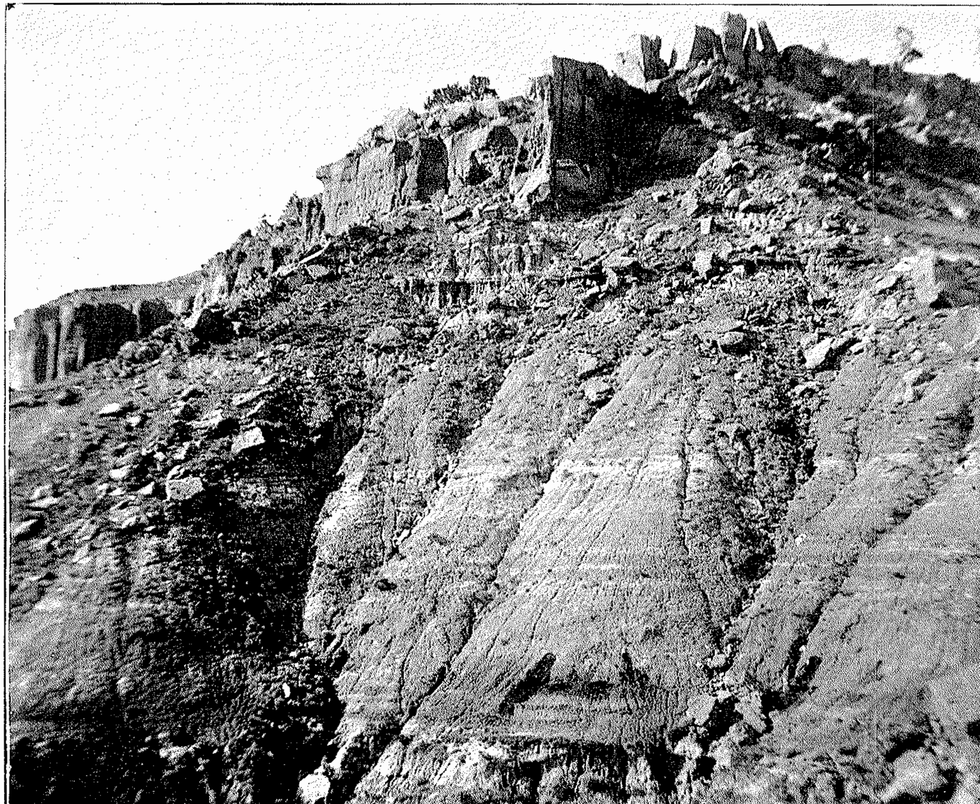
	Feet
5. A layer of buhrstone of fine-grained silicious quartzite	2 to 3
4. Slope of light gray clay	36
3. Rusty sandstone, 15 feet of which is exposed	40 to 50
2. Slope below estimated bottom of sandstone	115
1. Lignite exposed in bank of creek	5
Total	199 to 210

Section at the South End of North Cave Hills.

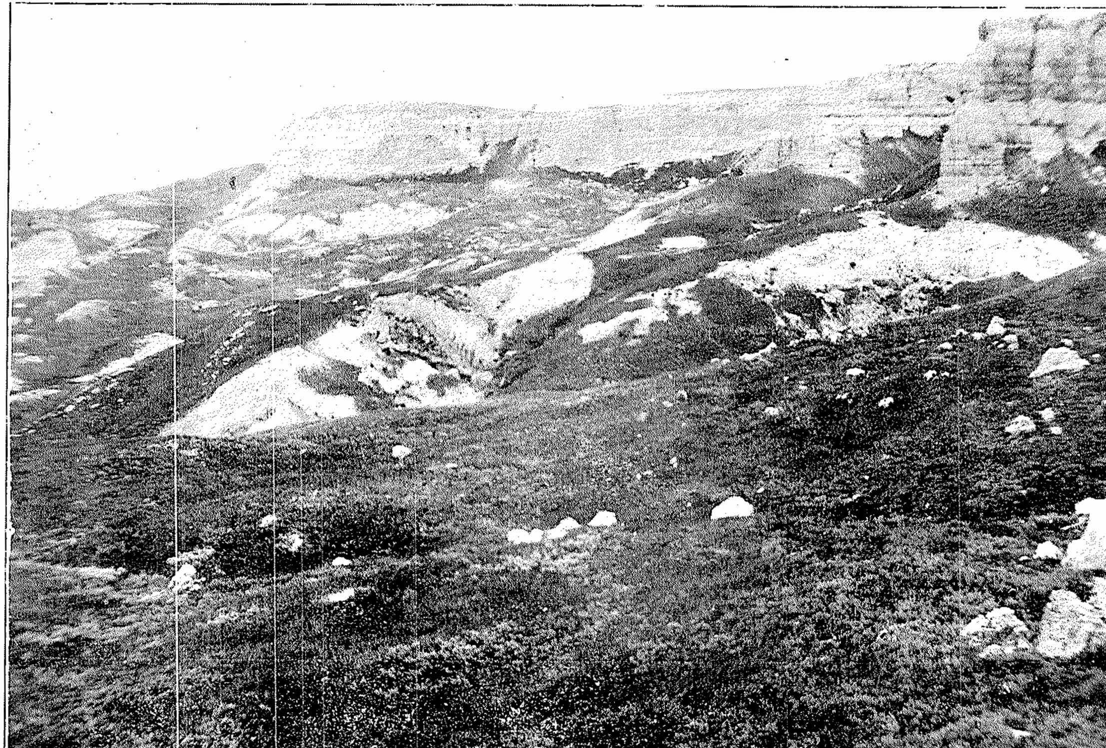
Top as high as any.

	Feet
57. Yellow fine-grained quartzite or flint with casts of plant stems	2
56. Whitish marl with thin layers of limestone above	18
55. Purple sandstone, massive	27
54. Gray and white clay, plastic	12
53. Yellow sandstone, massive	50
52. Soft yellow stratified sand	16
51. Hard sandstone	1
50. Yellow sand	6
49. Gray sand	6
48. Dark plastic clay	70 to 75

47.	Lignite	¾
46.	Dark plastic clay	11
45.	Good lignite	5
44.	Dark brown laminated clay	4
43.	Yellow sand	2
42.	Yellow laminated clay	10
41.	Dark laminated clay	3
40.	Loam	4
39.	Shaly limestone	½
38.	Loamy clay	5
37.	Dark laminated clay	3
36.	Lignite	½
35.	Yellow loam	5
34.	Laminated, ripple marked concretionary limestone	1
33.	Cream colored laminated silt	8
32.	Lignite	½
31.	Gray sand	55 to 60
30.	Laminated clay with lignite in the middle	1½
29.	Light colored sandy silt	6
28.	Lignite	⅔
27.	Cream colored sandy silt, with some yellow calcareons sandstone concretions	4½
26.	Dark laminated clay and two inches carbonaceons layer at top	4
25.	Quite pure lignite	5
24.	Light cream colored silt	6
23.	Light colored silt with flat concretions at the top	15
22.	Dark laminated shale, about one-half of it impure lignite	4
21.	Very light laminated shale	3
20.	Black shale	¼
19.	Light course sand, some small concretions	10
18.	Plastic clay with three black bands of lignite	7
17.	Black, very pure lignite	3½
16.	Light clay	3
15.	Break in section	30 to 35
14.	Cream colored silt, stratified	5
13.	Thin shaly calcareous sandstone	1
12.	Brown and gray clay silt	14
11.	Gray clay	1
10.	Lignite	½
9.	Silt slope	9
8.	Carbon streak with alkali	½
7.	Light gray clay	6
6.	Obliquely laminated rusty sandstone	1
5.	Yellow silt with some clay	8
4.	Lignite	¼
3.	Dark plastic clay	4
2.	Lignite with large pieces of wood	2
1.	Slope with alkali clay	10
	Total	470 to 490



The south end of North Cave Hill. Lignite bed five feet thick near the base.



North end of Slim Buttes; Sandstone cliffs 100 feet high. Page 53.

Lignite Bed, No. 10. Section near Bonnewell's. Page 53.

This gives the most continuous section yet found and may be taken as fairly representative of the Cave Hills.

Section at the Northeast Corner of Slim Buttes.

MIOCENE.—

	Feet
8. Soft white sandstone horizontally stratified	135 to 140
7. Dark to light gray clays, more or less contorted and with thin sandstone and sand, with the dip north by east and also 12 degrees south	100
LARAMIE.—	
6. Yellow clay	45
5. Soft massive sandstone	35 to 40
4. Lignite	2½
3. Dark clay	1
2. Lignite	5½
1. Dark and light gray clay easily slipping	50 to 60
Total	374 to 394

Section Near Bonnewell's. Sec. 12, T. 18 N., R. 7 E.

MIOCENE.—

	Feet
18. White sandstone showing frequent oblique laminations	70 to 80
17. White chalky clay, local	2½
16. Soft white sandstone	30
15. Gray plastic clay with pieces of yellow flint with casts of stems	6 to 10
14. Pure white sand	12
13. Cream colored plastic clay	50 to 60
LARAMIE.—	
12. Irregular stratified sandstone, yellow and argillaceous with some large concretions	45
11. Light colored marly clay	4
10. Lignite with some calcareous and pyrite concretions	10¾
9. Mostly silt and sand with yellowish plastic clay above	20
8. Light colored marly clay	5
7. Lignite	¾
6. Hard sandstone	½
5. Light gray loam	18
4. Good lignite	2½
3. Slope, mostly clayey	52
2. Sandstone	2
1. Slope, mostly clay or silt	36
Total	370 to 392

About a mile and a half southeast of Bonnewell's and east of "E 6" Gap, the strata below No. 16 are very much disturbed, being thrown into sharp folds extending east and west and dipping from 12 to 25 degrees to the south and southwest with numerous sharp folds most abrupt on the north, sometimes separating into faults. This disturbance has brought three or four layers of lignite, some of them five or six feet thick, to the surface. In some cases this has been burnt and left a record of the fact in masses of slag-like boulders which lie a few rods east of the gap.

Section near Florman's Coal Camp, on or near Sec. 23, T. 18 N., R. 7 E.

	Feet
MIOCENE.—	
24. Soil and soft white sandstone	20
23. Hard layers of sandstone forming a cornice and a layer six inches thick at the top, very hard like flint	5
22. Sandy white clay, cracking polygonally above, shading into thin bedded white sandstone below	12
21. Massive white, fine sandstone with small globular concretions, translucent within, the rock showing efflorescence where not exposed to the weather. There are some layers of reddish color and some even shaly	60
20. Reddish flat concretions	1
19. Stratified, white sandstone	6
18. Soft sandstone, full of vertical stalactite-like concretions, redder below	6
17. Massive argillaceous sandstone, weathering into globular masses and containing small globular concretions	15
16. Slope, mostly soft white sandstone	27
15. Gray clay with porous sandstone fragments and with several thin interrupted layers of sandstone obliquely laminated usually dipping to the north	18
14. Rusty clays and sand, some white places and occasional thin layers of limonite	10
LARAMIE.—	
13. Gray sand with thin layers of sandstone	10
12. Gray shale	3
11. Hard, compact, gray sandstone layer, very even and with few joints	10
10. Drab, stratified clay, weathering yellow	3½
9. Good lignite	5½ to 6
8. Yellow sand with print of palm leaves	1
7. Light drab stratified clay with leaf prints	2¾
6. Good shaly black lignite	9½
5. Laminated clay, yellow and drab with many leaf impressions	18
4. Lignite	4½ to 8
3. Dark dirt-like clay	10
2. Shaly with pieces of lignite	12
1. Lignite	2
Total	276

Section southeast of Calbrick's.

MIOCENE.—

		Feet
6.	A cliff of white, soft sandstone with globular concretions	80 to 90
5.	Gray plastic clay as is exposed in some places. Elsewhere a slope covered with a conglomerate composed largely of pebbles of white argillaceous sandstone	35 to 50
4.	Loosely consolidated layers of course gray sandstone, obliquely laminated	4
3.	Yellow clay and sand	6
2.	Layers of coarse gray sandstone ridges with some clay and sand between. Some layers of gray opal-like flint	24
1.	Slope, evidently mostly clay and loam	65
	Total	204 to 239

Numbers 2 and 4 are apparently a local development of the lower Tertiary which is quite conspicuous at this point, also about the "J. B." Horse Ranch, about two miles east on the other side of Slim Buttes. Traces of a similar deposit are found here and there toward the south and west, as will be noticed in the section of Deer's Ears.

Section at the "J. B." Horse Ranch.

		Feet
16.	Sandy clay rock, some layers obliquely stratified	27
15.	White sandstone obliquely laminated, with dip of the laminae 22 degrees north, 30 degrees west, of variable thickness	6 to 11
14.	White clay, with worm holes filled with sand	½
13.	Sandstone, very evenly stratified	1
12.	White clay with worn surface, and showing thin layer of grit above obliquely laminated	27
11.	Stratified whitish clay, the upper part with hepatic globules in a little sand, lower portion with layers of sandstone, heavy 2 to 3 feet	18
10.	White sand with thin layers of marly pebbles	12
9.	Greenish gray opalized sandstone, calciferous with white flat biscuit-like concretions	12
8.	Interstratified dark clay and sand	3
7.	Slope	23
6.	Gray sandstone	6
5.	Slope	20
4.	Stratified light gray silicious clay, cracking into cubes one-half inches in diameter	8
3.	Dark gray clay passing up into No. 4	6
2.	White silicious-like natural mortar	4
1.	Slope with a thin stratum of lignite exposed in spring near ranch at the bottom	40
	Total	323

Section at the southeast angle of Slim Buttes.

MIOCENE.—

	Feet
18. Clay, top of it flat with fragments of limestone	9
17. Coarse sandstone	2
16. Whitish clay	38
15. Light gray sandstone	4
14. Fine argillaceous sand rock	50
13. Coarse sandstone	9
12. White argillaceous limestone, lower six inches full of fossils of fresh water shells, very hard and sonorous	2 to 3
11. White clay	18
10. Sandy white clay	8
9. Fragments of buhrstone or yellow flint with plant stems	1
LARAMIE.—	
8. Yellow clay	50
7. Yellow sandy loam	5
6. Light gray sandstone with a layer of large calcareous sandstone concretions on top	4
5. Light colored clay sand with smaller concretions	9
4. Dark clay	10
3. Light gray plastic clay	7
2. Yellow sandy loam with several layers of calcareous sandstone concretions	54
1. Dark gray plastic clay	15
Total	296

Section of Deer's Ears Buttes.

MIOCENE.—

	Feet
10. Coarse gray conglomerate	6 to 8
LARAMIE.—	
9. Light yellow clay, blotched with dark tints	75 to 80
8. Rusty sand with some large globular concretions	3
7. Drab and yellow clay	40
6. Light gray clayey sand or silt	50
5. Dark plastic clay forming a conspicuous zone	8
4. Clay, mostly light drab	65
3. Drab colored sand with peculiar vertical seams filled with fibrous calcite or gypsum	8
2. Impure lignite	½
1. Drab colored clays with two or three sandstone layers	80
Total	342

Base of the Butte.

Similar alternations of drab colored clay and occasional sand continues 100 to 200 feet to the level of Sulphur Creek. The coarse gray sandstone seems to be identical with the gray sandstone in the sections at the "J. B." Horse Ranch and near Calbrick's. Boulders evidently derived from this stratum are scattered over the clays of the Ft. Pierre Formation on the elevated points nearly to the Black Hills on the south, and westward it was noticed about the Buttes on the head waters of the South Branch of the Moreau and Indian Creek. From appearance and their lying at the same level, there is little doubt that the summit of Castle Rock Butte is composed of the same material, also the higher points of Haystack Butte.

Section at the South end of the East Short Pine Hills.

	Feet
MIOCENE.—	
18. A soft fine grained white sandstone, many glob lar concretions from ½ to 1½ inches in diameter	260
17. Slope with very much disturbed surface apparently by weathering and undermining of a plastic clay	25
LARAMIE.—	
16. Yellow sand	18
15. Sand and clay interstratified	30 to 35
14. Sand	18
13. Clay	2
12. Lignite	½
11. Fine brown sand or loam, more clayey above	17
10. Yellow waxy clay	3
9. Clay with vertical seams filled with gypsum ½ to 1 inch thick	35
8. Chocolate colored loamy clay	2
7. Fine gray sand	6
6. A thin layer of lignite	¼
5. Slope mostly clayey	27
4. Lignite	½
3. Drab colored clay with fragments of large rib 2 inches across	12
2. Yellow sand and sandstone obliquely stratified and hardened to a quartzite above	15 to 20
FT. PIERRE (2).—	
1. Slope mostly dark colored clay to the level of a ravine at the end of the North Fork of the Moreau River	100
Total	579

Prof. N. H. Winchell, who visited the West Short Pine Hill in 1874, gives the following section derived mainly from the west side:

"1. White arenaceous marl, indurated, varying from harsh arenaceous lime to a sandstone with limy cement, cracking into small conchoidal blocks which soon crumble into soil in the air. It contains but little iron, but has a few argillaceous concretions. About 200 feet.

"2. Massive rusty sand weathering into pinnacles and isolated peaks. This is the same as seen on top of Castle Butte. 50 to 75 feet.

"3. Blue clay, locally varying into sand, seen. 110 feet."

He adds: "There are several interesting features connected with this clay above. First, it contains at different horizons what appear like concretions of sand. They are laminated, and the lamina are concentric, though the sandy masses are usually somewhat elongated. The sand on the outside of these masses is loose and friable, but the interior is firm and in most cases the inside of the mass is very hard, appearing dark colored and close grained passing into an argillaceous limestone. These masses or balls were not observed to contain any fossils. They are entirely isolated, in some cases closely inpacked in the clay, but usually lie in an interrupted course, having a parallelism with the stratification of the clay. It is apt to be coated with iron or an argillaceous iron ore."

He reports also the finding of two vertebrae of what appears to be Hadrosaurus, and also a variety of turtle bones. The Castle Butte to which he refers is not that so-called upon recent maps, but a butte, as we understand, a few miles southwest of Cave Hills.

The Laramie includes all of the strata in Cave Hills, with the exception of the two upper members and all in the Slim Buttes below and including the rusty sandstone, all also in Deer's Ears except the uppermost layer and those in the East Short Pine Hill with the exception of No. 1, which is probably Ft. Pierre. Some question may be raised as to whether a portion in the southern sections may not be properly correlated with the Fox Hills group, but we found no characteristic fossils to indicate that, nor does there seem to be any natural division by which we may separate the lower from the higher strata.

From these sections several facts appear. First, that there is in the upper portion of the Laramie a thick development of sand and sandstone in the vicinity of the Cave Hills which is thinner toward the south and east. This may be due to the thickness of deposition or more likely to erosion. The appearance of the junction of the Tertiary with the Laramie in the North Cave Hill and also in the South Cave Hill strongly suggests a beach with an eroded cliff.

Second, the Laramie is made up of layers of lignite, loam, clay, and sandstone very unevenly deposited, especially the fragmental beds. A comparison of sections a few miles apart shows no very close correspondence.

Third, the fossils, so far as discovered, are of fresh water origin. In beds near the northwest corner of Slim Buttes a stratum a few inches in thickness was found to contain many shells resembling a Melantho. Remains of turtles and large reptiles were found at several points.

Fourth, the lignite beds apparently thicken toward the north and west. In the Cave Hills there are prevalently found a thick stratum 5 to 7 feet in thickness, 150 to 200 feet below the top of the sandstone and another 100 to 125 feet below that. The two are found in the same section only at the south end of Cave Hills, but this is probably due to the greater depth of erosion. Ravines and valleys at other points probably fail to reach the lower stratum. The upper stratum was traced eastward for 25 or 30 miles along the valley of the North Fork of the Grand River. This layer also corresponds it would appear with the thick layers appearing in the Slim Buttes sections, and as near as can be judged it corresponds with a thick layer reported from the Long Pine Hills, west of the Little Missouri. The two thick beds in the section at Florman's Coal Camp, with comparatively little material between, may be found to correspond with the two thick beds in the Cave Hills. In that case it would seem that the successive areas of deposition of coal diverge toward the north and possibly to the west.

Fifth, the sands below the uppermost layer are frequently unconsolidated and are apt to contain elongated concretions, sometimes closely resembling saw logs in size, shape and outward appearance. They are found lying at the same level in streams from a few feet to a few rods in width and extending for miles in the direction of their elongation. Sometimes a single rock-like concretion may extend 50 or 100 feet, divided of course by joints running crosswise. Sometimes a number may be more or less joined side by side, and in some cases they pass into a stratum of sandstone of ordinary shape. They usually show rippled structure, and the cementing material is principally of carbonate of lime. These are the same, apparently, referred to by Prof. Winchell in his section of the West Short Pine Hill. Otherwise, we do not know that any reference has been made to them or similar structures by others. They may be found figured in an article in the American Geologist, June, 1896, and more fully described under the head of "log-like concretions."

THE TERTIARY FORMATION.—There is little doubt that the two upper layers of light colored clays and marls of the Cave Hills sections and similar light colored and coherent portions of the Slim Buttes, Short Pine Hills and Deer's Ears are to be referred to the Tertiary. Fossils at the Slim Buttes indicate their Miocene age. These consist of a jaw, apparently of some turtle, and other bones of no characteristic value; a skull is also reported from the same beds which appears from description to have been an Oreodon. From the fact that there was apparently erosion of the Laramie surface, these beds are referred to the later Tertiary. The uneven surface is doubtless the result of erosion during the Eocene. Moreover, Mr. Abner Anderson, of Vermillion, has shown me teeth and fragments of characteristic bones of a Titanotherium which he picked up northeast of the Short Pine Hills. The character of the rock as well as the disturbances occurring between the formation of the earlier and that of the later, furnish good reason for referring them to the White River and Loup Fork groups of the Miocene.

THE WHITE RIVER GROUP.—Under this head we include the fossiliferous flint or buhrstone, which is found widely scattered over the surface of the Laramie, not only around the Cave Hills, but as far east as the principal moraine east of Napoleon, No. Dak. This resembles very closely in texture and color the buhrstone from the Paris basin. It also has irregular cavities in it, many of them clearly traceable to the stems of plants which vary in size from one-sixteenth of an inch to three or four inches in diameter, and have such positions as would correspond with the view that the stone was formed around stems in position. The angle, the branching and the roughness of the surface all agree with this supposition. A few cases have been found where the wood was still in the cavity. It was solidified, although not so solid as the surrounding rock. About the Slim Buttes at this horizon are found frequently deposits of an impure opal of a yellowish or gray color, and very generally the clays are scattered with silica which has been deposited either in the form of thin veins or of coralloidal masses. In this respect the beds of the Slim Buttes resemble those described by Dr. Hayden along the White River. It seems not unreasonable to suppose that while the lake to the east and south was deep enough for the accumulation of marl, silt and sand, there were extensive marshes around the border of the lake in which silica was deposited around the stems of plants while they were in their natural position. While, for the most part, the blocks of this fine grained quartzite, or buhrstone, are scattered over the surface of the Laramie, they are rarely found in what may be considered their natural position.

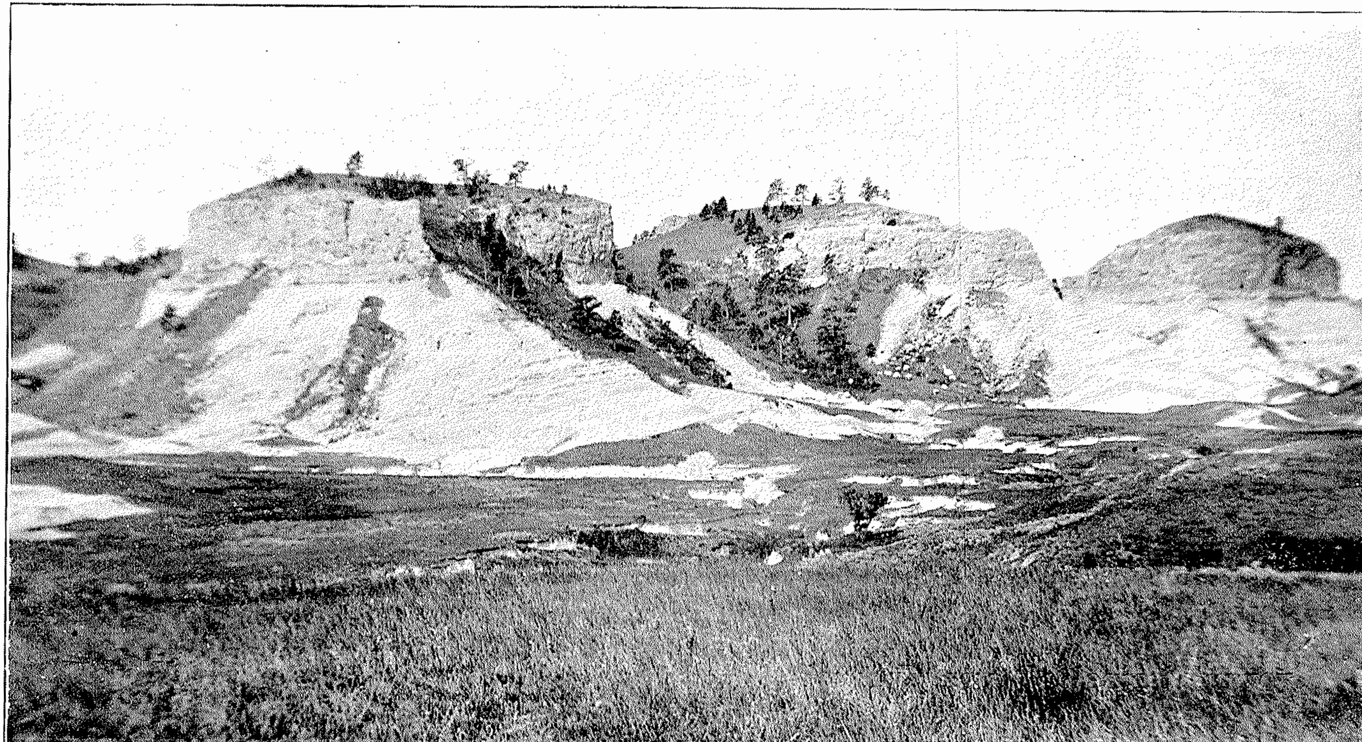
One place of this sort was found about a mile north of Ludlow's Cave, another toward the south end of the North Cave Hills. My observation agrees with that reported by Professor Winchell, namely, that they are never found over an area occupied by the thicker development of the White River Formation. It would seem, therefore, that some such theory as we have stated would be corroborated by this peculiar distribution. It seems unreasonable to refer them to the Laramie, for in that case we should find them underlying the Tertiary. They form a most suggestive fact concerning the history of this region during the early Miocene. We would include under the White River all of the light colored strata of the Slim Buttes up to the break separating the disturbed beds from the horizontal undisturbed above.

About "E 6" Gap the thickness of these beds is something over 100 feet. At Calbrick's it is about the same: and there we find, also, a development of a coarse gray sandstone which is apparently a comparatively local formation most prominently developed in that portion of Slim Buttes and traced southward and southwest in thinner beds and further on in detached blocks as far as the Belle Fourche. It seems not unreasonable to suppose that this development of the upper portion of the White River may be ascribed to the action of a stream, or streams, discharging from the Black Hills into the ancient lake to the northeast. A similar arrangement of coarse sandstone or conglomerate is also conspicuous, extending from the Black Hills eastward to the vicinity of the Cheyenne, and even to the White River east of Hermosa. It seems not improbable that a deposit of this character is that alluded to by Newton as underlying the Tertiary along French Creek.

Beside the reasons given for correlating this formation with the White River group, should be mentioned that the character of the beds repeat almost identically the Titanotherium and Oreodon beds which are described by Dr. Hayden along Sage Creek and the White River. In the thinner portions of this formation, as along the edge on the top of Cave Hills, especially the South Cave Hill, and at the southeastern extremity of Slim Buttes, there are thin layers of fine grained, thin bedded, sonorous white limestone, in which are found numerous fossils of fresh water shells, including the genera Planorbis, Limnea, and Physa. These are silicified, while the stone is largely calcareous. When subjected to acid it is found, however, that there is a bulky argillaceous residue which interferes with the easy solution of the rock.

THE DISTURBANCE CLOSING THE WHITE RIVER.—We have already alluded to the disturbance of the Laramie and White River beds about "E 6" Gap. Their unconformity at that point is very clearly shown in Plate X. It is readily seen that the upper strata are clearly horizontal and of a different character from the lower inclined strata. The upper are mainly soft sandstone, while the disturbed beds are sand, plastic clay, and sandy clay deposits like mortar. Further south at the gap southeast of Calbrick's, a bed of conglomerate intervenes between the lower and upper strata, although both are horizontal. At the "J. B." Horse Ranch there appear places where the lower beds projected slightly into the upper as if certain points were at first above the water-line of the lake in which the latter began to be deposited. It scarcely need be added that the transition beds were largely composed of fragments of the lower, and that the strata of the upper formation were frequently obliquely stratified. At the northeast angle of the Slim Buttes the lower member is much more thinly developed; and, although there are traces of disturbance sufficient to produce contortion, there is no clear extensive dipping of the rocks as at "E 6" Gap.

THE LOUP FORK BEDS.—The rocks believed to belong to this formation may be briefly described. There is no such variety of structure or composition as is found in the preceding formation. Everywhere it consists of a fine-grained, white friable sandstone, often thickly studded with small globular concretions; and, usually where it has not been long exposed



Loup Fork Beds resting upon inclined White River Strata, near "E 6" Gap, or North Gap, Slim Buttes. Page 53.

to the weather, showing brisk effervescence with acids. A few layers are quite dense as though cemented with silica. These are exceedingly hard and may perhaps be called quartzite. The concretions also show frequently in their interior a translucent character and a dark color. The thickening of this formation apparently increases to the south, at the north end of Slim Buttes to about 125 feet in thickness. At the northeast angle 135 feet, near "E 6" Gap about the same. At the southeast angle of Slim Buttes it seems to be absent; in the Short Pine Hills it shows a development of about 200 feet. No fossils were found in it. One remarkable thing concerning it is the almost perfectly horizontal chararacter of its upper surface. This is true both of the Slim Buttes and the Short Pine Hills, and it seems very probable that we have here the original surface corresponding with the water-level of the lake in which it was deposited.

ECONOMIC NOTES.

The specimens collected have not yet been carefully examined and tested. Hence we are unable to speak confidently concerning the economic value of several things which seem quite promising.

LIGNITE.—From the sections recorded above it will be seen that beds of workable thickness are found at several points. There is considerable variation in quality of the lignite, some beds being very largely composed of clay, while others are quite pure. Some have numerous flattened tree trunks constituting their main substance, while others, have a nearly homogeneous character and easily break into blocks like coal. From the former small pieces of a very compact and pure character with shining lustre, may be obtained, while the mass of the bed is less compact and usually more impure than in the latter.

A view of a thick bed near Bonnewell's is shown in Plate IX.

One serious obstacle to the mining of the lignite seems to be in the general absence of sufficiently hard material to form a safe roof. There were but two places found where a bed of stone occurs at the top of the lignite stratum. One was the upper thick layer at Florman's Coal Camp, the other in an inclined bed east of "E 6" Gap. In all other cases the overlying stratum was of clay slightly consolidated. At Riley's, east of Cave Hills, there were but a few feet of clay covering the lignite over considerable area. In such cases the clay might be easily removed with plow and scraper and large quantities of good lignite readily obtained. Though this absence of firm roof seems unpromising, yet the beds have practically the same roofing here as is reported from North Dakota where the lignite is mined in considerable quantities. Doubtless the difficulty may be largely overcome by ingenious engineering. In some of the beds, as in the 10-foot bed near Bonnewell's, considerable masses of pyrite and carbonate of lime occur. These, however, may be found of little hindrance in a bed of that thickness.

No tests as yet have been made of the heating power of the coal, nor have careful analysis been made. There seems little doubt, however, that the coal will correspond closely with that found in North Dakota. From a report by Prof. E. J. Babcock, of the University of North Dakota, we learn that lignite from a bed at Dickinson, N. D., gave the following analysis:

Water and volatile matter	52.59
Fixed Carbon	43.02
Ash	5.39

Of an average of 20 samples of North Dakota coal,

Water and volatile matter	48.37
Fixed Carbon	44.71
Ash	6.92
Sulphur	.34

From his interesting report we also quote a comparison with coals from other regions:

Ohio coals: average of 20 analysis, Ohio Geological Survey, 1883.

Moisture and volatile matter	36.65
Fixed Carbon	58.10
Ash	5.12

Iowa coals: average of 64 analysis, Iowa Geological Survey, 1870.

Moisture and volatile matter	47.81
Fixed Carbon	45.42
Ash	6.77

He says, further: "For general heating purposes the value of coal can be estimated by the fixed carbon it contains. By referring to the analysis, the fixed carbon of the North Dakota coal analyzed averages 44.71, that of Iowa 45.42, showing that the North Dakota coal is almost as efficient as the Iowa coal for heating. For heating locomotive boilers most of this coal might not be economical for general use, since it would perhaps be difficult to arrange a locomotive draft and grate suited to other kinds of coal which would not waste the lignite."

"For general manufacturing and heating purposes in which most of the fuel is used, the coal of North Dakota is well adapted. By the use of the native coal hundreds of thousands of dollars might be kept in the State and encouragement given to the development of an important resource."

Comparing it with other coals, he calls attention to the following advantages: First, purity of fuel. These coals are almost always quite free from earthy matter. Second, they contain less iron-sulphide. Third, the ash is quite free from clinkers. We understand that recent increase of the price of the eastern coals has greatly increased the demand for North Dakota lignite. We may be encouraged to expect more from this resource when we learn that at present large quantities of this material, probably no better than our own, is used in Germany and Austria. It is stated that twenty-two million tons of this fuel are annually used in those countries for domestic and other purposes.

Prof. Dumble, of the Texas survey, in 1891 published the results of his study of the use of the European lignites. He states that from some of the brown coals in Styria valuable supplies of light and heavy oils and of paraffine are obtained. Also that the material is prepared for fuel for domestic use by pressing it into coal bricks and briquettes. The former is done by mixing the lignite with water and compressing it with machinery. Briquettes are made in some cases by thoroughly drying the lignite, pulverizing it, then compressing it under a pressure of from 1,500 to 2,000 atmospheres. The resulting briquette is of a lozenge or elliptical shape some six inches in length and about one inch in thickness, very firm and durable. The compression is so perfect that the briquette will not absorb water if it be laid in it for some time. The earthy brown coal is preferred for briquette making on account of the ease with which it is pulverized. Another method of making briquettes, practiced in Styria, is by cementing it with strong coal pitch. Most of the lignites burn easily with considerable flame. In manufacturing, advantage is taken of this feature by distilling the gas from the lignite and using it in the smelting of iron.

From these facts we derive a more hopeful view of the value of the lignite deposits of the northwest in which our State has an important share.

BUILDING STONE.—Sandstones of the Tertiary are unsuitable for building purposes, and limestone is only rare, occurring in a few thin strata. The sandstone of the Laramie, however, especially that capping the Cave Hills, is massive, abundant and of quite durable quality. The most of it exhibits in its natural condition a tendency to weather in an irregularly cavernous manner. This seems to be due to the presence of carbonate of soda or some similar salt. It is believed, after a somewhat hasty survey of the hills, that with some care valuable quarries might be opened for local use.

BUHRSTONE.—As we have before indicated, there is found over much of the northwestern part of the State a peculiar fine-grained, silicious rock, occurring for the most part as scattered boulders, but oftentimes these are very abundant. Pieces of the size of from one to two feet in diameter are easily obtained. The stone has almost exactly the color and texture of the buhrstone from the Paris basin. It has also a somewhat porous character, the openings, however, being due to the stems of plants instead of some other cause as in the French stone. It seems not unlikely that in case there is any demand for a stone like the foreign buhrstone, this supply might be used to advantage.

BARITE.—Professor Winchell in his trip across the region found thin seams in some of the clay beds of the Laramie which were filled with a fibrous mineral. These he found in the third member of the section of the Castle Butte, and by subsequent tests found it to be barite. In our examination we saw nothing which suggested the existence of barite, but we were not on the lookout for such material. This is a valuable mineral and if found in quantities might be no inconsiderable source of revenue.

TIMBER.—The whole region outside of the Black Hills is without trees, except the scattered, narrow groves along the principal streams which consist mainly of cottonwood, with occasional ash and elm, and the trees in the upper portion of the ravines about the Cave Hills, Slim Buttes and the Short Pine Hills. These trees are mostly red pine, which rarely exceed 25 or 30 feet in height and a diameter of a foot. These are found sufficient to furnish material for log houses and for fuel, although in some cases the lignite is preferred for the latter purpose.

GRASS.—The remainder of the region is covered more or less thickly with grass, with the exception of areas sometimes of several acres near the streams or where erosion is most rapid, which are bare, and constitute what is commonly called "bad land." Limited areas might be found which repeat quite exactly the Bad Lands of the Little Missouri on the Northern Pacific, or when formed of Tertiary clays, the Bad Lands along the White River. The grasses vary according to the geological formation and the character of the subsoil. The Fort Pierre clays are quite uniformly covered with the so-called "alkali grass" or wild wheat, which resembles wheat in appearance. It does not grow very thickly nor often to a height exceeding six or eight inches. Nevertheless, it is considered a very nutritious grass, in the dry season equal to grain in value. Much of the Fort Pierre area seems to have been overfed and weeds are taking the place of the native grass. The country underlaid by the Laramie formation shows a greater variety of grasses as some of the strata are nearly pure clay, much resembling the Fort Pierre, and others are loam or even sand. We find in some places the alkali grass, in others grasses much resembling those of Iowa growing taller and more thickly. Of the particular species we cannot speak confidently, but judge it to be the same that is called in other places "blue joint." The summit plain of the Slim Buttes and Short Pine Hills is covered with quite luxuriant grass, so also the bottom along the large streams, particularly the North Fork of the Grand River and in the broader valleys it grows more luxuriant than further south upon the cretatious Fort Pierre.

WATER.—The larger streams as the branches of the Grand and Moreau Rivers and the Little Missouri are rarely without running water and of very good quality. Other streams are very copious in the Spring and after rains, but in drier seasons of the year they are reduced to water holes of considerable size. All of the streams are subject to freshets which oftentimes come quite suddenly. A little care would do much to retain the rainfall, which seems to be quite abundant, by the damming of smaller streams and by the excavation of artificial basins at convenient points in the clay. The latter has been done of late north of Belle Fourche to provide water at easy distances for fat cattle as they are brought to the railroad at Belle Fourche. In the gulches of the Cave Hills and

Slim Buttes springs are not infrequent. This is no doubt due to the extensive deposits of sandstone and sand found there. The springs seem to be rather copious and numerous along the east side of the Cave Hills.

The region is, as a whole, well adapted for grazing. The water is sufficiently abundant, grasses are nutritious, the broken areas afford natural shelter, while the more open level areas are well adapted for pasture. The variety of soil, the irregularity of surface afford such variety of food as seems especially advantageous for the convenient pasturing of stock. As the country becomes more settled and communication is opened with the eastern part of our State, the mining of the lignite will doubtless become some day an important industry.

J. E. TODD.

The Geology Along the Burlington & Missouri Railway.

Through the courtesy of the general manager of this railway, Mr. Holdredge, it was my privilege to make a rapid tour over this line in 1895 and I have supplemented it by another in 1898. It affords a rare opportunity to become acquainted with the peculiar structure and scenery of the Black Hills. It traverses the hills from north to south, and within the State has a vertical range of nearly 3000 feet. It affords unusual opportunities for comprehensive views, especially as it passes over the top of Terry's Peak; and exhibits fine examples of engineering skill, particularly in descending the canyon of Spearfish Creek. It enters the State a little north of Pine Ridge, in the valley of Hat Creek, and passes nearly due north to Deadwood, sending off branches to Sheridan, Wyo., Hot Springs and to the mouth of Spearfish canyon.

Before entering upon a detailed description of the journey, it is well for the reader to gain a general view of the peculiar structure of the Black Hills, as well as to recall a few prominent points of geological history.

The Black Hills are an irregular dome-shaped uplift rising 3500 hundred feet above the surrounding plain, or 7500 feet above the sea. In its elevation it seems to have pushed up the overlying formations and burst through them, especially along the east side. The later formations lie at the angle of 40 to 50 degrees, dipping away from the center of the hills on all sides. The interior of the hills consists of dark colored slates and schists standing up nearly vertically, and worn into jagged peaks or gentle slopes, according to the degrees of hardness. These slates with masses of granite which lie in them, belong to the oldest gelogical time, known as the Archean or Eozoic. Resting upon the slates on all sides are the brown sandstones known as the Potsdam, which is 150 to 250 feet in thickness. Overlying this is the Carboniferous formation containing 400 to 500 feet of limestone, capped with 200 to 300 feet of colored sandstones, the latter usually of red color; over this 300 or 400 feet of marly clay, in which is a layer of purple limestone or marble about 40 feet thick, which are referred to the Triassic. As the latter are easily worn away, their location is marked by a red valley encircling the hills on every side. On this formation lies 400 to 800 feet of sandstone divided into several separate beds, separated by clay and shale. Most of the lower portion are usually of a reddish color and are referred to the Jurassic period, while the upper are of a yellowish brown and belong to the Cretaceous. These sandstones stand as a rampart 300 to 500 feet in height, surrounding the hills, forming their more distinct boundary. On the outside overlying the sandstones are thick deposits that form the surrounding plains, consisting of grayish clay, with occasional layers of calcareous concretions, or thin beds of sandstone. These constitute the so-called Colorado formation.

The accompaning cut, Figure I, exhibits a general section across the Black Hills from east to west, according to the earlier view of Newton. To adapt it more perfectly to later views, the later beds should be somewhat less inclined than the older and unconformities between the Potsdam and Carboniferous, and between the Jurassic and the Cretaceous should be shown.

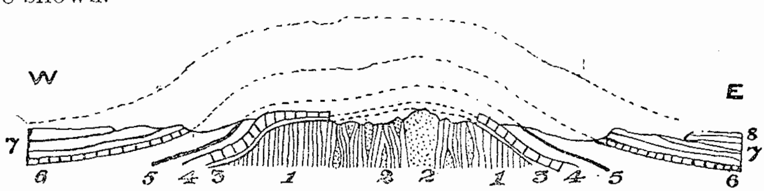


FIGURE I. SECTION ACROSS THE BLACK HILLS, ACCORDING TO NEWTON.
1. Archean schists and slates. 2. Granite. 3. Potsdam. 4. Carboniferous. 5. Red Beds. 6. Jura. 7. Cretaceous. 8. Tertiary.
The dotted lines show amount of erosion.

Ardmore, the first station after entering the State, is located upon the upper layers of the Colorado formation, or as some may classify it, the lower portion of the Montana. A boring 1500 feet in depth revealed only bluish shale, except thirty feet of white sandstone with some water, at 1300 feet. The sandstone is probably a layer of the Niobrsra. The boring was not carried far enough to tap the Dakota Artesian supply. Nor would that come to the surface by about 250 feet, judging from the results obtained at Edgemont. The surface is clothed with sparse grass, and shows the undulation commonly appearing as the result of erosion upon the western plains. From Ardmore to Rumford the railroad follows the valley of Hat Creek. From that point the grade turns to the northwest, follows up a valley-like depression until it reaches the summit at Provo. To the south of that station a sharply cut ridge of insignificant height is the distinguishing feature. In it a little further on, a shaly sandstone, probably of the Niobrara, appears at about the level of the station. Descending to the valley of Cottonwood Creek, on the west, little attracts the attention until the shaly limestone ledge, belonging to the lower Niobrara portion of the Colorado, appears. Following down the valley of Cottonwood Creek, Edgemont is reached, the last station before entering the hills. From this point appears the valley of the south branch of the Cheyenne, and beyond it the imposing ridge of Dakota sandstone.

A bed of quite valuable coal has been discovered five or six miles east of this point. Its workable extent has not yet been determined. West of Minnekahta the same bed has been traced, but is not of sufficient thickness for profitable working. These belong to the same geological formation as the well known beds of Cambria and New Castle in Wyoming.

Within the next six miles the railroad climbs up the ridge reaching the center of it at Chilson. From that point an extended view of the valley of the Cheyenne to the south is seen. From this point the road, although still ascending, seems to pass between the higher points of the ridge and enters the Red Valley, which is there three or four miles in width. Minnekahta station is the junction of the branch which runs eastward along the Red Valley to Eureka, where it enters the higher land on the north through a gap in the purple limestone. Soon after, it meets Warm Brook, it breaks from the Carboniferous rocks on the north, and follows it with the descent of nearly 700 feet from Minnekahta to Hot Springs, which is again in the Red Valley. This valley attracts common attention on account of the brick red soil. Much of it lies in a favorable condition for farming, and with sufficient moisture is quite fertile. It contains valuable deposits of gypsum everywhere, especially above the purple limestone.

Hot Springs has deservedly become a prominent pleasure resort. It is located in the valley of Fall River, which above the town divides into two streams; one called Hot Brook and the other Cold Brook. These streams seem to be mainly formed from subterranean channels breaking from the inner side of the valley. In the vicinity of the town are high ledges of conglomerate lying forty or fifty feet above the station. These are of recent origin, probably dating from the Glacial epoch. By undermining, the cliffs have been broken into large blocks giving an impressive air of wildness to the ravine. This terrace extends widely in the valley and a larger part of the town is built upon it. It is about 100 feet above the level of the stream. Along the inner side of the Dakota ridge, south of the gap, is another conspicuous terrace not so wide as the first, about 160 feet higher. Traces of this are also seen upon the opposite side of the gap. This was the highest terrace noticed. It seems not unlikely that it corresponds in level to the heavy terrace deposits around Wind Cave, which mark, as we believe, the period of rapid erosion corresponding to the Glacial period. In this part, however, the agency was water alone without the action of ice. Between these two terraces are two or three stages which are less conspicuous. Southeast of the town is a high point of Dakota sandstone. North of Hot Springs about ten miles is another attraction to the vicinity known as Wind Cave, which is noted for its numerous intricate passages and delicate frost-like crystals, unique "box-work" and stalactites. The traveler is peculiarly impressed in passing along the stream above Hot Springs in seeing a large Persian water-wheel doing its part in irrigating the valley.

At Hot Springs valuable cement works have been erected for the proper preparation of gypsum, which is abundant in this vicinity as elsewhere in the Red Valley.

The locality of Minnekahta has attained considerable notoriety among geologists because of the recent finding near there of low stump-like petrified tree-trunks of a palm-like pine, called Cycad. These are believed to belong to the early Cretaceous epoch, and probably may be found at other points around the hills. They have been reported from Hot Springs and Rapid City.

From Minnekahta the railroad follows the Red Valley northward gradually climbing the east slope until attaining sufficient altitude, it suddenly turns eastward and passes through a notch in the purple limestone. Between Argyle and Pringle we pass through cuts of fine red Carboniferous sandstone. At Pringle we are in the shadow of the high Carboniferous limestone ridge on the west, with little, if any, exposure of the Potsdam sandstone at the base. On the gentler slopes to the east and north, we see ragged patches of dark colored slates standing nearly erect, but dipping toward the east. The Carboniferous limestone is seen almost in contact with the slate. Here we bid farewell to the stratified rocks which we do not again see near at hand until we reach Deadwood. Pringle is 4884 feet above the sea, the highest point yet reached along our path.

As we pursue our course, we begin to notice that rising above the gentle slopes of the slate surface are narrow walls of coarse gray granite. These are from a few inches to several feet in thickness and rise from 5 to 25 feet above the surrounding country. These narrow ridges or walls run nearly north and south, and become higher and thicker till they become massive ridges 200 to 300 feet in height, as is found north of Custer. Indeed the towering mass of Harney Peak is but the culmination of a gigantic feature of this sort. The rougher portions of the country are thickly covered with small pines, all inside of the Red Valley. It was at Custer that the first traces of gold were found upon French Creek by the Custer expedition. Placer mining was at that place at one time very productive. Higher up upon the streams not only is considerable gold yet found in the valley, but at several points rich veins of quartz have been discovered. One great hindrance to the development of the deposit of these mines has been the scarcity of water; and requisite capital has not yet been invested to bring water, which may be obtained some miles away.

Through the kindness of Hon. J. E. Pilcher, I was enabled to visit a number of the more interesting points during my short stay. Numerous mining claims have been located in the vicinity. South of the city, about four miles, is the "Old Charley" mine, which is being profitably worked. I visited also the "Big Whale," about six miles, where promising prospects have been found in white quartz veins. At Tin Mountain a vein of granite contains considerable quantities of tin ore. Northwest of the city is a large mine of excellent mica. It has been worked so that tons of the mineral is in sight and it is of unknown depth. The refuse mica is utilized in an axle-grease factory, which has been recently started in the town. A few miles to the north is Sylvan lake, which is becoming more and more popular as a pleasure resort. Its altitude, beautiful surroundings, its excellent hotel and fragrant pine woods make it an ideal place for a few weeks' vacation in midsummer. Harney Peak with its grand views is not far away.

At Berne the railroad reaches its highest point in the "Southern Hills," 5853 feet above the sea. There is then a descent to Hill City through a rough country, along the west base of Harney Peak to the head-waters of Spring Creek. Hill City is another point centrally located with reference to several gold and mica mines. The "J. R." mine and Golden Summit are near by, and Sheridan, noted in the days of placer mining, five miles northeast, while ten miles east is Keystone with its rich gold mines, the most noted of which is the well-known "Holy Terror." To the south of this point is the Etta mine, the original and most noted of the tin mines, while nearer Hill City is the Addie. The dip of the slates varies greatly on the north of Harney Peak, not only in direction, but also in amount. The slates not only in places contain small garnet crystals, but in other places staurolite and hornblende. From a study of the hills west of Custer, as well as in this region, it seems probable, though not proved, that these different kinds of slates mark different strata of original deposition and that their repetition may be found to indicate folds of strata. That the slates have been so crumpled and folded, has been shown unmistakably by recent studies along Rapid Creek, contrary to the opinion of Newton and other early observers.

Near Hill City we pass the northern limit of the granite ridges. The granite is generally of a coarse nature, of a light color frequently showing what is called pegmatitic structure. It is generally looked upon as of eruptive origin, having been forced between the slates when they were far below their present altitude and covered with unknown thickness of overlying rocks which have been removed to build up later formations. This central portion of the slate area shows high ridges thickly covered with pines with comparatively open and level parks between.

From Hill City the road rises over the divide between French and Rapid Creeks. The latter stream is crossed at Mystic and followed up the north branch to Rochford, where there are some promising mines of gold and reported deposits of asbestos. Another summit is reached at Dumont near Custer Peak, 6198 feet above the sea. The region is still underlaid by slates. The trend of the slates is not so uniform as might be inferred from earlier reports. We now begin to see bodies of a massive gray rock, generally known as porphyry. In some cases it is in dikes several feet in width, but more commonly in huge wedge-like or dome-like masses. The latter form is not readily comprehended at first, but appears from closer study. At Englewood in the distance are seen occasional dark brown masses of stratified rock nearly horizontal. These are layers of the Potsdam sandstone. They are frequently in this region impregnated with gold very finely divided, which is free milling after exposure, but generally the ore is often "refractory."

At Deadwood we reach the terminus of the main line in the bottom of the canyon of Whitewood Creek. On either side the hills show conspicuously the masses of white Carboniferous limestone, with dark brown cliffs of Potsdam below. Between the two, close examination reveals twenty to thirty feet of buff arenaceous limestone containing Silurian fossils, and as much of greenish shale. The White Rocks east of the city belong to the Carboniferous, as also those north of the smelter. An eruption of porphyry has raised the stratified rocks east of the city 100 or 200 feet, forming dikes and sheets between them as well as below. And from it the Potsdam sandstone has been impregnated with gold, which produces the mines of Spruce Gulch and also some in the gulches west of the city. I am indebted to Mr. I. A. Webb for showing me through the former.

Nearly two miles below the city is a fault having a throw of more than 100 feet, running east-southeast, the down throw being to the south.

Northeast of this fault is a broad, dome-like mountain suggesting the presence of the Iaccolite as its core. It forms a very conspicuous feature just east of Whitewood Creek, as the Hills are approached from the northeast. The fault is doubtless connected, if not in direct continuation at least in time, with the very sharp fold lying just east of Boulder Prairie on the road from Deadwood to Sturgis. Boulder Prairie is a basin occupied by the Red beds of the Triassic. The purple limestone disappears with a gentle dip to the east on the west side of the basin, and along the east side is a very sharp anti-clinial fold with the direction south 32 degrees east. This fault brings up the purple limestone and underlying formations so that Bear Butte Creek has cut down nearly to the middle of the cliff limestones of the Carboniferous. The west side of the fold is very steep, but on the east side the rocks dip from five to eight degrees. Without doubt these faults and folds are to be referred to the eruption of the porphyry, which was attended elsewhere with the formation of valuable mineral ores. It is probable therefore that such deposits may be found in that vicinity.

At Lead City there is the noted Homestake mines and mills, running over 700 stamps, working away day and night upon a vein of lean but easily worked free milling ore. Over this is an outflow of white and variegated porphyry, in and under which are thin strata of Potsdam sandstone quite rich in refractory gold. These ores have been though to flittle value at the Homestake mills, but the improved methods of the chlorination and cyanide processes have rendered them available. The same may be said of similar ores from Spruce Gulch, already mentioned, and of the whole rich mining region which lies southwest of Lead.

In the slates, we found a trace, as it would seem, of a great fold running northward. A stratum of impure iron ore seemed to be the most obvious clew to its position. This stands nearly vertical, parallel with the bedding of the slates. It was noted east of Lead, about three-quarters of a mile west of Deadwood, and also crossing the gulch a little west of Central City. What evidence it may give of the arrangement of the original deposition of the slates and perhaps of valuable mineral deposits, may require much study to determine.

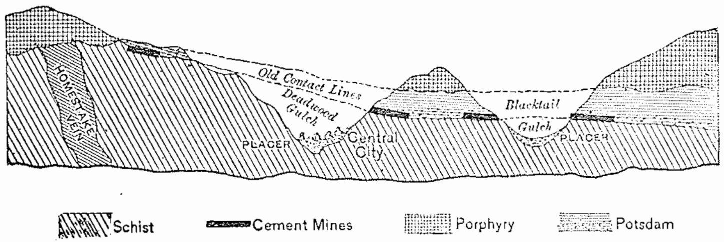
Englewood, a point north of Dumont, is the junction of the Spearfish branch. The railroad, from this point, gradually climbs the north flank of Terry Peak, reaching its highest point at Portland 6425 feet above the sea. From this place a most magnificent view may be obtained on a favorable day, of not only the Bald Mountain district, and of the main points around Deadwood, but also of Bear Butte, the northeast cornerstone of the hills, as it were, and of Crow Peak, similarly situated on the northwest, but of the whole scope of the country drained by the Belle Fourche River, with the various buttes occupying the higher portions of the divide beyond, from which rise the

Moreau and Grand rivers. Castle Rock and Haystack buttes standing out prominently, with the Deer's Ears, strongly suggesting their name, and beyond them the Short Pine Hills nearly due north; and a little east the glimmering white walls of Slim Buttes, the last being over eighty miles away.

Numerous prospect holes on the sides of the valleys skirting the mountain, with the narrow gauge railway going in and out between them, mark the valuable mines of Bald Mountain and Ruby basin districts.

The gold ore is usually indicated by simple blackening in the rock in or near the veins of porphyry,—which term we use in a comprehensive sense to include other igneous rocks. The ore is sometimes vein-stuff and at other times country-rock. The layers of the latter especially likely to carry gold are the upper heavy sandstone layer of the Potsdam and also the lower conglomerate layer, commonly spoken of as the "upper contact" and the "lower contact." Other layers also seem to be rich probably from the local distribution of iron pyrites in the original rock.

The sub-joined cut, Figure II, assists in presenting these relations. It was not made particularly for this purpose, however. The cement mines, those shown, exhibit the "lower contact." The upper layers had not attracted much attention as gold-bearing, when this cut was made. Moreover, the porphyry sometimes is intruded between the layers of sandstone as well as above them.



Approximate Geological Sketch from Homestake Vein, Eastward.

FIGURE II.

The quartz or pyrites in these layers seem to have had an affinity for the gold which was dissolved in the waters attending the formation and filling of fissures when the porphyry was intruded. This porphyry which usually is a kind of trachyte has not only filled large vertical fissures from a few feet to several rods in width, but has been thrust in between the layers of stratified rocks, forming sheet-like or dome-like masses between them. The top of Terry Peak and Elk Mountain are largely covered with bare patches of angular blocks of trachyte which have been derived from large vertical dikes. Such kinds of lava as are deposited upon the surface have not been clearly found in the northern hills, hence we may consider that vast thicknesses have been carried away by erosion, and we have but the lower portions or roots, so to speak, of the original mountains.

Not only is the gold found in the Potsdam formation, which is a most reliable and rich source, but also in the overlying limestones of the Trenton or Carboniferous as in the case of the Ragged Top and vicinity. The Potsdam sandstones are very much raised by and more or less mixed with the igneous rocks. The summit cut in the railroad just west of Portland shows several feet of the Potsdam sandstone, and as the railroad winds in and out around the heads of the gulches similar cases not infrequently occur, though the trachyte is a more common rock. Although the Potsdam disappears toward the west under the more recent formations along the line of the railroad, it is revealed again in the bottom of the Spearfish Canyon and along the sides of the Canyon. As the Canyon is deepened the sandstone appears higher. A little west of Elmore it rises 100 feet or so above the bottom. Opposite the mouth of Little Spearfish about the same height, but it sinks below the level of the stream a little north of Maurice. It does not exhibit very conspicuous cliffs, though at two or three points the upper layers may stand with a height of 25 feet. It is more often represented by a slope covered with vegetation. Near Maurice there is a dike of trachyte which cuts through the Potsdam, ending abruptly above in an irregular dome-like top overlaid by the Trenton. This dike seems to be connected with Little Crow Peak and ore of paying value has been found in the vicinity. It is interesting to see how this dike was arrested by the overlying limestones so that it did not affect the original surface and would not have been suspected had not the Spearfish Creek cut down across it and revealed its existence and relations. It shows for perhaps a mile and a half. It is of a finer grain than the variety which appears in the dike of Terry Peak and Elk Mountain and contains no distinct crystals.

Just east of Crown Hill depot there is a cut showing the Trenton limestone with large Orthocerata similar to those found at Deadwood. A little further west a bluish shale overlies it like that at Deadwood, which is called Devonian. Both of these formations are found covering much of the Crown Hill property to the north, and north of Crown Hill depot a large mass of Carboniferous limestone is a conspicuous feature. The Trenton limestone from its position between two formations of shale and its own massive character, seems to have been especially apt to be carried up over the dome-like masses of igneous rock. The Carboniferous limestone from its great thickness and massive character, seems to have resisted quite successfully the movements of eruptive rocks wherever this overlying mantle of limestone was great. We therefore find the general surface of the Carboniferous, as around Spearfish Canyon, forming extensive tablelands comparatively horizontal, while the upthrusts of Terry Peak, Elk Mountain, Ragged Top and others, tower above it and the Trenton limestone seems to be carried up nearly or quite to the summits. A distant view of Ragged Top from the top of Elk Mountain seemed to show the Trenton limestone covering nearly the whole of that peak. The elevation of Trenton limestone at Crown Hill must be considerable over 6000 feet above the sea. This formation appears quite conspicuous in the sides of Spearfish Canyon from the mouth of Annie Creek to the mouth of Squaw Creek. It increases in thickness toward the northwest so that at Maurice it is about ninety feet in thickness, while the overlying shale between it and the Carboniferous seems to be lacking. This Trenton limestone, which has also been called the Deadwood formation, is a bluish sandy limestone which weathers to a buff color. Besides the large Orthoceras mentioned, a species of Halycites is quite common. In some layers it may be perhaps more properly called sandstone. It is quite massive and at several points, especially opposite and near Maurice, it forms a conspicuous cliff underneath a more prominent one of the Carboniferous.

The main part of the sides of the Spearfish Canyon are formed of the massive gray limestones of the Carboniferous. I saw no distinct trace in that vicinity of the Minnelusa sandstone, which usually occupies the upper part of the Carboniferous. The plateau in which the canyon has been cut is of a comparatively even upper surface, due probably to the uniform removal of the sandstone and durable character of the limestones. Some parts of the canyon seem to exhibit the whole series of limestones, though no careful study of it was made. In the vicinity of Little Spearfish the upper portion of the limestones had evidently been removed near the canyon.

From a little west of Portland the railroad begins its descent into Spearfish canyon, which lies not far away upon the west. Though we are informed that the road goes to Spearfish nearly due north, we find that we are turning south and even east. We begin to recognize, not only the red sandstone of the Carboniferous, but also the massive cliffs 200 to 400 feet in height, which mark the walls of the canyon. By following a quite crooked course, the bottom of the canyon is reached 4 or 5 miles south of the point where we first strike it; and we find ourselves disputing the right of way in the bottom of the canyon with a vigorous, clear stream rushing over large boulders and among dark spruces. The beauty of the canyon has been in a measure destroyed by the burning of the forests which were first covered with a thick growth of pine and now leaves instead black vertical trunks studding the cliffs. This occurred according to one tradition about 20 years ago. The course down the canyon is full of surprises, as we catch glimpses of the walls from time to time which seem to increase in height and grandeur.

The Little Spearfish coming from the southwest, just before its junction with the main stream, forms an imposing cataract about 40 feet in height of unique character. Its formation seems to be due to the following conditions: The Little Spearfish is charged with quantities of carbonate of lime which is deposited as travertine, as around some large springs. This, instead of being compact and solid limestone, is rendered impure by sediment and wash from the hillsides adjacent, so that it is in places quite soft and generally dark colored. It forms a terrace about 40 feet in height above the Spearfish Creek and seems still accumulating. It is not unlikely that Little Spearfish not long since was divided into several smaller streams which were scattered over this terrace for a distance of 10 to 12 rods, but at present the stream is united in one. While this delta has been accumulating, the main stream, which is here eroding the Potsdam sandstone, has been cutting its channel deeper, so that the two influences have produced the result described. The railroad crosses the Little Spearfish a few feet from the fall which forms one of the scenic attractions of the line. Enough water oozes through the rock to keep it moist, and moss covers much of its surface. Along the rock front of the terrace the travertine is formed in thin sheets or stalactite shapes so that it suggests the idea of a petrified cataract, much more extensive than that composed of water.

Just before reaching Spearfish we passed again through a V-shaped notch of purple limestone and came out suddenly upon the gentle slopes of the Red Valley. This lies open, particularly toward the northwest down the valley of Spearfish Creek. In the distance are seen the spurs of the Dakota sandstone, running in from the north and east. One of these culminates just east of the town of Spearfish and forms Lookout Mountain, so called from its use in early times when the first settlers were watchful of the hostile Indian. Upon this mountain is a valuable quarry of sandstone. From its summit a magnificent view is easily obtained of the valleys of the Spearfish and Red Water, and also eastward over Centennial Prairie to the vicinity of Whitewood. Spearfish Creek may be made to furnish enormous water-power, which, eventually, will be utilized not only for the separation of valuable ores found in the mountains southeast, but also for manufacturing for the population which in time will occupy the valleys to the north. Easy irrigation will cause the country to blossom like a garden. Twenty miles to the northwest a fine quality of coal has been found, the extent of which, though not yet determined, is continually promising more and more to the patient prospector.

As we passed over this branch and marked the engineering feats employed in its construction and saw how few were the stations along it, we were led to enquire for what purpose such an outlay had been made, especially as we were repeatedly told the line falls very much short of paying expenses. But with the hints already given of the future prosperity of the region, we may not wonder that the enterprising company of the B. & M. railway should be quick to perceive and preoccupy this desirable point. At the same time, we can heartily recommend this line to those who would desire to spend several days in studying and inquiring into the wonders of nature and invigorating mountain air, without the expense of a more distant trip to the more frequented places along the Rocky Mountains and in the far west.

Our visits at the points indicated, having been necessarily very brief, we shall live in the hope of studying more closely and at leisure the problems connected with Spearfish Canyon, the massive lava outflows about Terry Peak, and the intricate folds of the slates and schists of the central core of the Black Hills. The latter, especially, we hope may throw valuable light upon the origin and distribution of the valuable ores and mines for which the Black Hills are already widely known.

J. E. TODD.

Elevations in and About the Black Hills.

The United States Geological Survey has finished five topographic sheets covering most of this region, named after the principal towns in each, Oelrich, Hermosa, Rapid, Deadwood and Custer. The Edgemont sheet is not yet surveyed. We have also the railroad profiles of the Burlington & Missouri River Railway and the Fremont, Elkhorn & Missouri Valley Railway. From the latter we have the elevations of the stations, and by that we mean, the elevation of the track at the depot, and also bridges over important streams. From the government survey, we have elevations which are definitely marked, and all of these classes may be considered accurate. We have besides undertaken to give with less accuracy the elevations of towns away from the railroad, and of the junctions of important streams. In these cases, we have estimated from the topographic maps. In the case of towns, we have chosen as the definite point the principal cross-roads or forks, in the latter case, the elevation of water at ordinary stages. We think that these estimates may be relied upon as not having an error of more than ten feet either way, especially in more even localities.

ABBREVIATIONS.—B.—Burlington & Missouri River Railway. F.—Fremont, Elkhorn & Missouri Valley Railway. G.—United States Geological Survey. E .—Estimate from topographic map.

Locality.	Authority and	Altitude.
Ardmore	B	3557
Argentine	B	3676
Argyle	B	4798
Aztec	B	5898
Bakerville	E	4550
Bald Mt	E	6550
Battle Mt	G	4431
Battle Creek and,—		
Tepee Creek	E	4000
Foster Creek	E	3750
Squaw Creek	E	3330

Bear Butte	G	4422
Bear Butte Creek and,—		
———— Creek	E	3900
Volunteer Creek	E	2860
Spring Creek	E	2780
Beaver Creek and,—		
Antelope Spring Creek	E	3490
Belle Fourche	F	3018
Belle Fourche, bridge	F	3019
Belle Fourche, water at the bridge	F	2993
Berne	B	5853
Black Hawk	F	3493
Boxelder Creek and,—		
———— Creek	E	4850
Jim Creek	E	4370
Bogus Jim Creek	E	4175
Brennan	F	3114
Brownville	E	5500
Buena Vista	B	3742
Buffalo Gap	F	3250
Buck Spring	E	5450
Buck Spring Creek and,—		
Gillette Creek	E	4650
Bull Dog Ranch	E	5825
Carbonate	E	4750
Central City	E	4858
Centennial Park	E	4000
Cheyenne River and,—		
Bridge north of Edgemont	B	3437
Dry Creek	E	3160
Cheyenne Falls	E	3080
Horse Head Creek	E	3110
Fall River	E	3020
Cheyenne River, north of Smithwick, bridge	F	2942
" " " " " water	E	2921
Sand Creek	E	2945
Beaver Creek	E	2940
Lame Johnny Creek	E	2860
Chilson	B	3798
Crook Tower	G	7140
Crook City	E	3700
Crow Peak	G	5772
Custer	B	5309
Custer Peak	G	6812
Deadwood	B	4539
Deadwood	F	4531
Doc. Doty Ranch	E	3900
Dumont	B	6195
Edgemont	B	3453
Elk Creek	E	4875

Elk Creek and,—		
Little Elk Creek	E	3395
Elk Mt.	G	6423
Elmore	B	5220
Englewood	B	5597
Erskine	B	3822
Etta Mine	E	4400
Fairburn	F	3308
Ft. Meade	E	3325
Galena	E	4800
Garden	E	5050
Glendale	E	4280
Grashull	E	3125
Gregory	E	5800
Green Mt.	G	5222
Harney	E	4150
Harney Peak	G	7213
Hayward	E	3775
Hay Canyon Butte	G	3440
Hermosa	F	3298
Hill City	B	4982
Horsehead Creek, and—		
Black Banks Creek	E	3430
Beef Creek	E	3390
Lone Well Creek	E	3300
Hot Springs, Union Depot	B	3447
" " Elkhorn Depot	F	3440
Ivanhoe	B	4412
Keystone	E	4280
Kirk	B	4998
Lead, passenger depot	B	5089
Limestone Butte	E	3500
Little Crow Peak	G	5389
Little Spearfish	B	4971
Lookout	E	4980
Lookout Peak (Spearfish)	G	4478
Loring	B	4687
McQuaig	E	6325
Marietta	B	3496
Martin's Valley	E	3650
Maurice	B	4476
Mayo	B	5182
Merritt	E	5080
Minnekahta	B	4166
Mountain	E	5900
Mystic	B	4863
Nahant	B	5634
Nasby	E	5450
Odell	F	3306
Oelrichs	F	3342

Oreville	B	5344
Otis	E	4300
Pass Creek and Hell Canyon	E	4830
Pactola	E	4560
Perry	E	5400
Piedmont	F	3472
Piedmont Butte	G	4172
Pilot Knob, near Merritt	E	5450
Pluma	B	4736
Portland, mine	B	6372
Portland	B	6425
Portland Summit	B	6439
Preacher Spring	E	6550
Rapid City	F	3197
Rapid Creek and,—		
Two miles above Rochford	E	5400
Castle Creek	E	4850
Salt Creek	E	4825
Deer Creek	E	4350
Prairie Creek	E	3970
Redfern	B	5639
Richmond Hill	G	6060
Rochford	B	5224
Rockerville	E	4150
Rumford	B	3503
Runkle's	E	4075
S. & G. Ranch	B	3706
St. Onge	B	3427
Savoy	B	5899
Sheep Mountain	G	6050
Silver	E	4650
Silver Bell	B	5898
Sheridan	E	4600
Smithwick	F	3245
Spearfish	B	3647
Spearfish Creek and,—		
Annie Creek	E	5050
Little Spearfish	E	4730
Iron Creek	E	4625
Squaw Creek	E	4300
Spearfish Peak	G	5773
Spokane	E	4050
Spring Creek and,—		
Newton Fork	E	4450
Rockerville Gulch	E	3490
Squaw Creek	B	4472
Sturgis	F	3380
Sugar Loaf Peak	E	6030
Summit Siding	F	4858

Sylvan Lake	E	6100
Terry Peak	G	7070
Tilford	F	3522
Tunnel 1 on Deadwood Line	B	5147
Tunnel 2 on Deadwood Line	B	5041
Tunnel 3 on Deadwood Line	B	4860
Tunnel 4 on Deadwood Line	B	5474
Vincent	B	3522
Whitewood	F	3643
Whitewood Creek, east of Whitewood, bridge	F	3605
Whitewood Creek, east of Whitewood, water	F	3595
White Rocks, near Deadwood	E	5350
Windy Station	G	3563
Wind Cave	E	4050
Woodville	E	5900

J. E. Todd.

Additional Notes on the Limits of the Main Artesian Basin.

In this paper we purpose embodying some of the more significant data gathered upon the subject since the publication of Bulletin No. I of our Survey. These, we arrange under the following heads:

Data concerning the geographical limit.

Data concerning the lower geological limit, or depth of "bed work."

Data from wells recently bored by the U. S. Government.

All of the data given were gathered prior to or independently of those collected by the United States Survey and published in its Seventeenth and Eighteenth Annual Reports except as is definitely acknowledged. It will be seen by comparison of those here given with the reports mentioned that in a number of cases statements have not been exactly in harmony. Where there have been important variations, we have aimed to distinctly indicate the differences.

First, concerning geographical limits. More careful examination has failed to materially change the eastern limit of the artesian area which was published in Bulletin No. 1 of the Survey, and which has again been quite recently and more widely published in the "Official Divisional Map of South Dakota," issued by the South Dakota Immigration Association. Although this is true, it has been discovered that flowing wells from the same supply have been obtained at Marshall, Minn. From data furnished by those personally acquainted with the facts we learn that nearly 400 feet of drift and shales are penetrated before reaching a stratum of sand which furnishes copious supplies of water with a closed pressure of about 75 pounds per square inch. Moreover, the water has similar mineral properties to those on the James River valley. This is of special significance to our citizens, as it suggests the possibility of obtaining deep artesian wells along the eastern slope of the Coteau des Prairies in our own borders. The pressure height of the Marshall wells is 1360 feet above the sea.

Marshall, Minn.—At that point are two wells known as the Town well and the Mill well. The former is reported by Mr. J. C. Burchard as having a "depth of 396 feet, the main flow coming from 380 feet, the closed pressure 80 pounds, and water hard and flowing 80,000 gallons," presumably for a day. The Mill well, reported by Mr. W. F. Geisike, has a depth of 392 feet, the main flow coming from 381 feet, pressure 75 pounds, water containing 199.59 grains per gallon, composed of magnesia, lime, soda, ammonia and potash, sulphates and carbonates, also sodium, chloride, iron oxide, aluminum and silica.

Section beginning about five feet above the railroad depot:

		Feet.
1.	Blue shale with a few hard layers	381
2.	Sand rock containing water	11

Blue clay or shale was found below it.

Upon the high land between the James river and the Missouri, sometimes called the Eastern Coteau, several efforts have been made to obtain flowing wells, and although water has been struck in most cases, the pressure has been insufficient to raise it to the surface.

Madison.—Through the kindness of Mr. Chas. B. Kennedy, I am enabled to give the following record of the deep boring made at Madison in 1891. The first 600 feet is given by Mr. Kerr, who bored the well:

	Formation	Thickness—Feet	Depth—Feet
1.	Soil and yellow clay	8	8
2.	Sand and gravel	10	18
3.	Blue clay	142	160
4.	Shale	40	200
5.	White clay	40	240
6.	Yellow sand	30	270
7.	Shale	220	490
8.	Lime rock	80	570
9.	White sand rock	3	573
10.	Marl	6	579
11.	Sandstone or granite		

NOTE.—This is thought not to be very accurate.

Another partial record is as follows:

1. Surface soil.
2. Gravel.
3. Blue clay.
4. Sand.
5. Blue shale, reaching to 450 feet.

Three different veins of water in the various sand strata. Limestone was encountered at 450 feet; blue and black shale

480; sand vein, water bearing at 570; hard sandstone light colored at 757; black or bluish mud or sticky shale at 655; coarser dark sandstone at 730; light and dark colored mud or sticky shale at 770; sandstone, light and finer at 1000; slate at 1018, continuing to 1082 when the work was stopped. From the specimens preserved by Mr. Kennedy, on which the depth were marked, the following notes were made after an examination with a magnifier:

875—dark plastic clay with fine grit.

890—like the last.

900—like the last.

937—like the last, a shade darker.

960—like the last, blotched with black and some rounded coarse sand grains.

1000—dirty gray rounded sand, less than .01 of an inch.

1015—exactly similar.

1021—very fine sand, dirty white, light gray, .001 to .002 of an inch.

1025 to 1040—light drab clay, with fine grit like the sand above.

1050—small black piece of carbonaceous clay.

1053—a thinly laminated drab clay, with sand layers between. Grains about .01 of an inch.

1080—a lenticular concretion 1.75 inches in diameter of pyrite in stratified sandstone, studded with several cubic crystals. Water was said to be found in a heavy stratum of sand, and it stood quite uniformly at 100 feet below the surface.

Webster.—Concerning the deep well at this place diverse reports have been made. From a communication, while it was being sunk, from the contractor, Mr. A. J. Ross, I learned that it was sunk to the depth of about 1550 feet, and that water did not rise to the surface, although sand similar to that in the wells at Andover and Britton and also water bearing was struck near the bottom. Yet private parties have informed me that at one time water flowed over the surface. Such is difficult to believe: first, because if pressure were found at that point sufficient to produce a flowing well at the height of about 1870 feet, the highest pressure attainable in the James river valley has not yet been found by several score of pounds. I visited the well in January, 1896, and found no evidence of water ever having flowed from its mouth.

DeSmet.—At this point a well was sunk to the depth of 1610 feet from a height about 1800 feet above the sea. No careful record seems to have been kept. A few specimens were found in the possession of one of the men employed in boring, Mr. Richard Worden, who gave me several valuable notes and showed me specimens upon which the depths had been marked. He said that water was believed to have been struck at the depths of 50, 200, 700, 1100, 1300 and 1400 feet below the surface, and that the water remained in the well at an altitude of about 50 feet below the surface. This corresponds approximately to the level of the surface water which is quite abundant in the valley adjacent. The elevation of the mouth of the well is about 25 feet above the railroad station or 1800 feet above the sea. Of the samples examined, gumbo or hard clay, occurs at the depths of 175, 723, 910, 920, 1035, 4045, 1095 feet. A fine micaceous sandstone at 1055 feet.

Mr. Worden gave an imperfect section from memory as follows:

	Formation.	Thickness—Feet	Depth—Feet
1.	Yellow pebble clay	50	50
2.	Fine sand, coarser below, with water	35	85
3.	Gumbo, with pockets of sand	75	160
4.	Gumbo	40	200
5.	Fine sand	100	300
6.	Shale, about,	400	700
7.	Uncertain	30	730
8.	Sandy shale and sand	30	760
	(Water from this rose to 50 feet below the surface.)		
9.	Uncertain, but probably shale	400	1160
	(The first water bearing sand quite fine, 763 to 793. A sample said to be one foot thick largely composed of fish teeth, from 1148 feet, and water at 460.)		
10.	Reddish brown limestone	6	1166
11.	Hard sandstone	20	1186
12.	Shale	4	1190
13.	Blue limestone	4	1194
14.	Hard sandstone with a stratum of gravel with water near the top	104	1300
15.	Chalk rock	30 to 40	1340
16.	Limestone and sandstone alternating, mostly hard,	270	1610

(Total depth commonly stated at 1610, though some doubt it.)

At 1160, after going through the cap rock, water rose to within 50 feet of the top. In a company of men more or less familiar with the boring of the well, the principal statements of Mr. Worden were considered correct. The more notable facts concerning this well are the occurrence of a stratum of fine sand about 200 feet below the surface, which probably corresponds to the pre-glacial sand (Pliocene?) and found north of Sioux City. According to the account there seems to be a clay without pebbles above it. There were rather uncertain reports of small bones having been found in it. It seems also probable that the quartzite was not struck in this well. A sample shown as from the bottom 1610 feet, was rather coarse, grayish and rusty sand, some quite opaque and white, others clear, all rounded.

From U. S. Geological Survey, Eighteenth Annual Report, Part IV, page 595, we add a log of the DeSmet well, furnished by Mr. J. J. Miller, chairman of the waterworks committee:

Log of Boring at DeSmet, S. D.

	Formation	Thickness—Feet	Depth—Feet
1.	Yellow clay	4	4
2.	Blue clay	40	44
3.	Sand	60	104
4.	Dark shale	736	840
5.	Cap-rock	25	865
6.	Sandrock, with water, to -40 feet	120	985
7.	Soapstone	200	1185
8.	Sandrock, with water to -40 feet	271	1456
9.	Very hard rock	14	1470
10.	Sandrock, with water to -20 feet	140	1610

A comparison of this with the section obtained from Mr. Worden shows several discrepancies, but the combination of the two will probably give more correct conclusions than either alone. It is to be noted that Mr. Worden, who worked with the driller, did not speak of the rock at the bottom as being especially hard.

Vilas.—Through the kindness of Supt. W. W. Girton, of Howard (now of Madison), I am informed that wells a little west of that place struck the water bearing stratum from which the water rose within about thirty feet of the surface.

From these notes and others reported in the bulletin, from Salem and Bridgewater, the conclusion that the eastern limit of the artesian basin coincides closely with the mark heretofore laid down upon the geological map in the Bulletin No. 1, of the South Dakota Geological Survey is corroborated. Additional facts bearing also on this point are mentioned under the next head.

There has been doubt in some minds about the extension of the artesian area, much west of the Missouri river. The lower pressure of the earlier wells at Pierre and at Chamberlain seemed to forbid the claim that pressure increased westward so as to keep pace with the rise of the country, but recent wells at Cheyenne Agency and at Pierre fully sustain the conclusion, urged by the State Geologist five years ago, that without much doubt the artesian area includes wide regions west of the Missouri even to the Black Hills.

The recent well at Pierre, S. D. is a very interesting and instructive case, giving important evidence on the geological limit as well as upon the geographical. The purpose of the boring was to ascertain the possibilities of obtaining large supplies of natural gas. For several years the presence of gas in that region has been known and has shown itself not only in shallow wells, which have simply penetrated the drift clay, but a much larger quantity from the artesian wells bored both at the Indian School and at Locke Hotel. Early in this year the boring which was done by W. E. Swan & Son, reached a hard rock at a depth of 1250 feet. Samples of this were submitted to the State Geologist and found to be gray granite similar to that struck about Hitchcock and Doland. This was so hard that it took four or five days to bore six or seven feet. The log of the well, as given below, is copied from the one kept by Mr. Swan:

Log of Pierre Natural Gas and Power Company Well.

	Formation	Thickness—Feet	Depth—Feet
1.	River sand	10	10
2.	Sand and gravel	52	62
3.	Gray shale	25	87
4.	Black Shale	39	180
5.	Black Shale	95	275
6.	Blue shale	50	325
7.	Light gray shale	100	425
8.	Dark gray shale	51	476
9.	Lime rock (hard)	3	479
10.	Blue shale (cavey)	51	530
11.	Lime rock (hard)	3	533
12.	Blue shale (cavey)	67	600
13.	Blue shale (firm)	50	650
14.	Sandstone (hard)	4	654
15.	Blue shale (firm)	40	694
16.	Blue shale (cavey)	391	1085
17.	Streaks of lime and shale	45	1130
18.	Sand rock (yellowish)	10	1140
19.	Streaks of lime and sand	35	1175
20.	Sand rock (yellowish)	10	1185
21.	Streaks of shale, lime and sand	30	1285
22.	White sand (soft)	30	1245
23.	Streaks of white shale and lime	25	1260
24.	Quartzite or granite	3½	1263

Number 1 carries a little gas, No. 13, in upper portion, carries gas in quantities. Water began to run over top of pipe at 870 feet in No. 16. Another small vein at 890 feet. No gas with this. Good flow of water and gas from Nos. 18 and 20. The main flow of water and gas was struck in No. 24. The six inch pipe is down to No. 17. The eight eight pipe rest on No. 14. The ten inch pipe rests on No. 3. Pressure of upper flow tested 210 pounds per square inch. Temperature of water 89 degrees.

Mr. Chas. L. Hyde, who has prominent connection with the company sinking the well, writes that a final measurement showed the well to be 1256 feet deep, seven or eight feet of which were in the granite. The mouth of the well is three or four feet lower than the depot which would make it 1436 A. T. and the top of granite 188 A. T.

In 1894 an artesian flow was obtained at Belle Fourche. The record below was given from memory by Mr. F. A. Dunt, who bored the well:

Log of Belle Fourche Well.

The mouth of the well is about 3025 feet above sea level.

Formation	Thickness—Feet	Depth—Feet
1. Shale	207	207
2. Sand	100	307
First flow at 245 feet.		
3. Soft clay	118	425
Second flow from three feet of sand at 323		
Main flow from 418		
4. Sand	100	525
5. Black Shale, stopped at		525

It is probable also that the wells at Sheridan, Wyo., and Miles City, Mont., are fed from the same supply as our own.

A gradient rising about four feet per mile westward corresponds well to the pressure height as observed at the following wells: Marshall, Minn., Huron, Miller, Highmore and Belle Fourche, S. D., and Sheridan, Wyoming.

Another well about two miles south of Rapid City and 320 feet deep has been reported to me by Prof. F. C. Smith, formerly of the School of Mines. It is said to be in a valley and its altitude may be placed, with considerable doubt, at about 3200 feet above the sea. It was bored about three years ago. The record given by the one who sunk the well is as follows:

Log of Well near Rapid City.

Formation	Thickness—Feet	Depth—Feet
1. Gravel	20	20
2. Shale containing coaly seams	250	270
3. Sandstone	50	320

The flow is about six barrels a day.

Other attempts to obtain artesian wells have been made at different places about the Black Hills. At Buffalo Gap, Mr. F. A. Dunt, the same man who bored the Belle Fourche well, bored about 945 feet, starting considerably higher than the depot, and found nothing but blue shale. From the dip of the beds, we count it probable that he stopped a very little short of the top Dakota formation, which doubtless would have furnished water, though probably not a flowing well.

The Burlington & Missouri River Railway have made several borings along their line to obtain suitable water for their engines. At Edgemont they bored about 1000 feet, mostly through shale, and struck sandstone which furnished water which rose within 150 feet of the surface. At Ardmore borings were carried to a depth of about 1500 feet, wholly in shale, except about thirty feet of white sandstone at about 1300 feet, which carried a little water of bad quality. A deep boring was made at Minnêkahta to a depth of 1360 feet. This was mainly through the red beds of the Triassic and stopped short of the red sandstones of the Carboniferous, which would probably furnish an abundance of water. It is very desirable that this boring should be carried further. The possibility of water in the Carboniferous sandstone and in the Potsdam sandstone might be quite satisfactorily tested by going 2000 or 3000 feet. When we remember the altitude of the beds and the fact that they must absorb large quantities of water and that there is no known exposure of these beds within several hundred miles, it is not at all improbable that sufficient head might be found to cause a flow at an altitude as low as Minnekahta. As we have remarked in another place, it is not improbable that some of the copious springs throughout the Hills, such as Cascade and the head waters of Hot Brook, may be supplied from this source. Their opportunity for escape is through fissures caused by disturbance of strata.

The following records of the borings mentioned above are furnished by the courtesy of the B. & M. R. R'y Co.

Log of Edgemont Well.

	Formation	Thickness—Feet	Depth—Feet
1.	Soil and gravel	28	28
2.	Shale	360	388
3.	White sand rock, water	40	428
4.	Shale	70	498
5.	White sand rock, water	150	648
6.	Black shale	135	783

7.	Red sand rock, water	45	828
8.	Shale	162	990

Log of Minnekahta Boring.

	Formation	Thickness—Feet	Depth—Feet
1.	Soil and gravel	12	12
2.	Gypsum	425	437
3.	Red sand rock	465	902
4.	Gypsum, water	200	1102
5.	Red shale	130	1232
6.	Black gypsum	44	1276
7.	Red sand rock	84	1360

This is doubtless wholly in the Triassic Red Beds.

Second, to illustrate the lower or geological limit of the Dakota formation, within the artesian area the following sections are given:

S. S. Budlong's well: This is located on the southwest quarter of Sec. 18, Twp. 114, Range 62, Spink county, three miles north and three miles east of Hitchcock. It was bored by Mr. P. J. Stacey. The following record was kept and was reported to me both by Mr. Budlong and Mr. Stacey:

	Formation	Thickness—Feet	Depth—Feet
1.	Black loam	1	1
2.	Yellow clay	11	12
3.	Yellow sand	82	94
4.	White soapstone	16	110
5.	Dark shale	149	259
6.	Hard shell rock	.5	259.5
7.	Dark shale	80	339.5
8.	Light shale	25	364.5
9.	Iron pyrites	1	365.5
10.	Dark shale	43	408.5
11.	Sand rock, flow	12	420.5
12.	Hard strata	1	421.5
13.	Sand shale	35	456.5
14.	Sand rock	2	458.5
15.	Dark shale	101	559.5
16.	Hard strata	66	"559"
17.	Dark shale	44	603
18.	Hard strata	33	604
19.	Dark shale	36	640
20.	Hard strata	.5	641
21.	Soft shale	11.5	652
22.	Pyrites	1	653
23.	Dark shale	19	762
24.	Harder	1	673
25.	Shale	10	683
26.	Iron pyrites	1.5	685
27.	Hard sand rock, flow	2	687

28.	Dark shale	18	705
29.	Pyrites	.16	
30.	Dark shale	5	710
31.	Pyrites	.33	
32.	Gray shale	20	730
33.	Pyrites	.5	731
34.	Gray shale	25	756
35.	Harder	.5	
36.	Gray shale	20	776
37.	Sandy shale	10.5	787
38.	Hard sand rock	3	790
39.	Sand rock softer; flow, 75 gallons per min	12	802
40.	Conglomerate sand rock (concretionary with casts of leaves resembling elm, etc.)	18	820
41.	Sand rock; flow, 75 gallons	5	825
42.	Dark shale	10	835
43.	Sand shale	12	847
44.	White shale	19	866
45.	Conglomerate	25	891
46.	(Sand rock dry?)	12	903
47.	White shale	19	922
48.	"Quartzite," coarse gravel	23	945
49.	Hard and soft streaks, sand rock	7	952
50.	Very hard sand rock	13	965
51.	Rock (fine-grained, gray granite)	47	1012

Boring was carried on in this hard rock for several feet and finally it was satisfactorily shown at about 1025 feet that the rock was a very fine-grained granite of light color. The difficulty of boring seemed not much different from that found several feet above. It is probable that the boring was carried several feet in the granite, and that the borings were misinterpreted, because of the abundance of fine sand which was allowed to enter from the loose strata above. This demonstrates that the granite rises to a height of nearly 300 feet above sea level at that point. A similar rock was struck in the Motley well a few miles east at a similar depth. This was a surprise, because surrounding wells as at Hitchcock, Redfield, and other points further east going to nearly the same depth, had failed to find anything but loose sedementary rocks, while the Glidden well near Hitchcock had gone down to a depth of 1180, or to 120 feet above sea level. Near Conde a well went down to 262, all without penetrating granite.

At Aberdeen the boring had been carried on by Mr. Stacey to sea level. Gray granite was struck about forty feet above sea level. We should recall here from a former page that at

DeSmet, also, the borings reached to a point considerably below the bottom of the Budlong well, viz: 160 feet above sea level, without striking any but fragmentary deposits.

Eleven miles north of Alexandria.—A sample from this well was sent me by Mr. F. G. Butler, of Dover. He says that the well is near the northern boundary of the Sioux Falls granite, and the sample taken is from a depth of 500 feet. It was a dark, fine-grained crystalline rock, and on submitting it to Prof. Wm. H. Hobbs, of Madison, Wis., he gave the following very interesting report:

"The rock is an olivine diabase very much like that described by Prof. Culver and myself from Minnehaha county in your State. The rock is principally made up of a basic plagioclase with augite and magnetite with which are associated a few grains of olivine and a considerable number of blades of biotite. Several crystals of apatite of good size and considerable pyrite were observed. Areas of uralitic hornblende are associated with the augite and may be secondary after it. The felspar lath are rendered cloudy by alteration, zoisite being present as one of the products of alteration. The augite is of the deep purple variety common to the diabases and possesses in this rock noticeable pleochroism. The areas of magnetite are unusually large and are bordered by limonite."

Mitchell.—At Mitchell though several attempts have been made to obtain strong flows they have been unsuccessful. It is not, however, certain that quartzite has been the main hinderance, although it probably lies very near the bottom of the wells. The greatest depth yet reported is 575 feet.

Parkston.—At Parkston Mr. P. F. Kearns made an attempt, but was stopped at about 500 feet by some hard rock, presumably quartzite, though samples submitted were not sufficient to prove the fact. His record of the well is as follows:

	Formation	Thickness—Feet	Depth—Feet
1.	Gumbo	220	220
2.	Loose sand	50	270
3.	Gumbo	195	465
4.	Sand with water, producing flow	35	500
5.	Gumbo	20	520
6.	Pyrite and quartz rock, very hard		

The altitude of the Parkston well is 1393, and the mouth of the well is the same.

Menno.—This well was also bored by Mr. P. F. Kearns, who reported as follows:

A very hard rock, samples of which were submitted and clearly seen to be quartzite, was struck at a depth of 383 feet. The boring was carried on to the depth of 401 feet. The altitude of Menno is 1324. The height of the mouth of the well cannot be much different. The quartzite rises 940 feet above the sea.

Milltown.—The Hutterische community at that place have bored two wells on their place one-half mile north of Milltown. Mr. David Hofer has kindly given the following facts:

First, beginning fifty feet above the James River, which is there just about 1200 feet above the sea, after obtaining a slight flow, struck the quartzite at about the same level as in the second well. The second well began ten feet above the James River and struck the quartzite at a depth of 257 feet, and the boring was carried on 108 feet in the quartzite to a depth of 365 feet. The quartzite there rises 953 feet above the sea.

No distinct statements were made concerning the formations passed through, but the water was obtained in sand just above the quartzite. From samples submitted we have no doubt that the rock is the ordinary reddish quartzite exposed at Sioux Falls. Numerous other wells have more lately struck the quartzite in that vicinity.

Scotland Well.—In the latter part of 1894 the town of Scotland engaged Mr. W. E. Swan to sink an artesian well. He carried it to the depth of 668 feet. Hard rock having been struck which was found not to be the quartzite, though resembling it in color and in hardness, he closed his contract. Later, the town not being satisfied, the boring was pushed considerably farther, when softer rock was found, but as no water appeared the effort was discontinued. Mr. Swan gives the record of his boring as follows:

	Formation	Thickness—Feet	Depth—Feet
1.	Soil and yellow clay	15	15
2.	Hard pan	5	20
3.	Blue clay	22	42
4.	Cement clay	33	75
5.	Black clay	15	90
6.	Chalk rock	40	130
7.	Yellow sand rock	25	155
8.	Blue shale	40	195
9.	Gray shale	155	350
10.	Yellow lime rock	30	380
11.	Blue shale	35	415
12.	Sand rock, shaly	30	445

13.	Lime rock	6	451
14.	Mud vein	5	456
15.	Lime and shale, with streaks of red marl	20	476
16.	Sand rock, with streak of shale	34	510
17.	Red sandstone, hard	18	528
18.	Gray sand rock, soft	30	558
19.	Iron pyrites	2	560
20.	Sand rock, soft	25	585
21.	Sandstone very hard, pinkish color cemented firmly with carbonate of lime, with occasional layers of marl	83	668

A good vein of water was found in No. 7, rising to within 60 feet of the surface, also in No. 12, rising to within 6 feet. From No. 16 the water rose to the top and ran over slightly. The water from Nos. 18 and 20 increased the flow to about 90 barrels per minute with a pressure of 11 pounds per inch, water perfectly clear, calcareous. No. 21 has alternating soft and hard layers, but the soft contain no water.

After Mr. Swan discontinued the work, Mr. J. H. Baskin continued it and sent samples which were examined at the time and were surely not quartzite, in either the common or technical sense of the term. The sand rock continued, becoming somewhat lighter in color to the depth of 685 feet. The sample submitted from that depth contained many rounded grains of quartz $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter. These show very interesting enlargement with numerous small crystalline facets. There are also fragments of thin dolomitic veins and small crystalline concretions of pyrite. This continued to nearly 700 feet when three inches of pyrite was penetrated, and then white sandstone was struck. No samples of this were submitted. The borer thought it might be limestone, but it was doubtless sandstone with perhaps calcareous cement of seams. Most of the boring below 675 feet was comparatively easy. As there seemed little prospect of water, the work was discontinued.

The rational explanation of the facts seems to be that the softer layers below belong to the Sioux Quartzite formation, which had been imperfectly cemented, and this may have been partly due to the coarseness of the grains. The silica had not been deposited in quantity sufficient to fill the larger interstices.

Yankton.—During September, 1896, I was consulted concerning the city well of Yankton, the one located upon the west side of the city. The water had become insufficient and the city council had attempted to find stronger flows of water by going deeper. The original had been sunk to a depth of about 600 feet, and for this we give the original record as reported by the contractors, Messrs. Karr and Richey. From that depth to 880 feet the boring was carried on by Mr. P. F. Kearns, and later continued by Mr. Christian Gross to the depth of 929 feet. The combined record is as follows:

	Formation	Thickness—Feet	Depth—Feet
1.	Yellow clay with small streaks of gravel	45	45
2.	Chalk rock	40	85
3.	Shale and soapstone	160	245
4.	Hard sand rock	3	248
5.	Shale	105	353
6.	Sand rock	20	373
7.	Shale	37	410
8.	Hard rock	3	413
9.	Running sand with water	15	428
10.	Shale	17	445
11.	Running sand with water	30	475
12.	Hard rock	4	479
13.	Shale	27	506
14.	Hard flint or loose rock	2	508
15.	Coal	1	509
16.	Shale	26	535
17.	Hard sand rock	10	545
18.	Running sand with water	15	5C9
19.	Shale	20	580
20.	Rock to bottom	29	609

From consultation with those familar with the boring, Mr. Kearns' work was given as follows:

	Formation	Thickness—Feet	Depth—Feet
1.	Fine sand	196	805
2.	Clay	2	
3.	Sand	62	
	Last flow from 850 feet, soft water.		
4.	Greenish clay	7	
5.	A hard tough greenish rock, sprinkled with quite calcareous white particles effervescing readily, the green easily fusing	49	929

This rock is of crystalline character, and from the tests applied appears to be mostly labradorite with some quartz and calcite or dolomite. At any rate it is a novelty in this region. Prof. W. H. Hobbs kindly reports it as containing felspar, quartz and magnetite.

THE POSSIBILITY OF WATER BELOW THE RED QUARTZITE.

Numerous cases have been reported which have led some to believe that by penetrating the quartzite, water would be found. This view was urged by Major F. B. Coffin in his report to the Agricultural Department in 1891. It seems to be strengthened by cases where well-borers have struck a very hard rock which they have believed to be quartzite and afterwards have found copious flows of water. Such cases have been reported west of Hitchcock, also near St. Lawrence. Moreover, there have been numerous instances where well-borers have given up the work with the impression that quartzite had been reached, and yet much softer rocks have been found below. When the hard rock was struck in the Scotland well and afterwards proved to be a sandstone cemented with lime, Mr. W. E. Swan expressed the belief that what had been reported as quartzite hitherto from Plankinton and White Lake was probably this same rock. No well authenticated case has been reported of finding water after true red quartzite has been struck. There are some layers in the Dakota sandstone which are very hard and resemble the quartzite in color, but are cemented with lime instead of silica. A small exposure of this sort occurs a few miles north of Sioux City, Iowa, and some years ago it was advertised as a granite quarry. There are cases known where some of the strata of the quartzite formation have either not been cemented or have become disintegrated by some process. In the valley of Wolf Creek near Bridgewater there is a sand bed in the quartzite soft enough to be excavated with a shovel and pick. At Sioux Falls upon the west bank below the falls an exposure of gray sandstone is found which appears to be of the same age as the quartzite not far away. Layers of it are quite friable and none at that exact point are firmly cemented with silica. It seems not impossible that in very rare cases the quartzite may have remained unconsolidated and that this may connect with the artesian supply, but no such case has been discovered. An attempt was made, a few years ago by Col. J. H. Drake, to penetrate through the quartzite near a large spring on the bank of the Big Sioux, east of Sioux Falls. He hoped to tap the source of the water and bring it under control, so as to utilize it in the city. He bored 525 feet with a diamond drill, but it was all quartzite with occasional pockets of sand. "There was no water except once, and then afterward the water from a spring one hundred feet away was drained." Nothing was found except what might easily be explained by crevices in the quartzite, and no head of water was struck. Nor could we expect to find pressure in the quartzite sufficient to produce flowing wells unless there was connection with some formation extending to much greater height than any known exposure of that rock. It should be remembered that no formation could give it greater head except the Dakota, and that has been passed without success before the quartzite is reached.

THE PROBABILITY OF OLDER FRAGMENTAL ROCKS BELOW THE DAKOTA FORMATION.

The penetration of a hundred feet or more of white sandstone at Scotland and a similar experience in the northern part of Hanson county, reported by Mr. F. G. Butler, strongly suggests that older formations, the Jurassic or even Paleozoic rock. They occur in patches, if not continuously, between the Dakota and the crystalline rocks below. Distinct layers of considerable thickness of Paleozoic rock have been penetrated at Ponca, Neb., and at Sioux City, Iowa, at depths between sea level and 700 feet above. It seems probable that these formations extend northwestward around the promontory of red quartzite. That these formations are water-bearing, at least to any degree rivaling the Dakota formation in quantity or pressure, is disproved, judging from the result at the Sioux City well, and in other wells at Council Bluffs and Omaha.

THE GOVERNMENT WELLS.

In pursuance of a plan urged by Maj. J. A. Pickler in the U. S. House of Representatives, the government made appropriations for sinking wells in connection with the various Indian agencies in our State. These will serve the double purpose of meeting the local needs and at the same time affording tests of the possibility of obtaining artesian water.

The Rosebud Well.—The first effort was made in the Rosebud reservation. The point chosen by Captain Wright, who was then agent, was at an elevated point northwest of the agency near the head of Oak Creek, near the southwest corner of section 10, town 39, range 27, east. The elevation of the mouth of the well is estimated from comparison with the geological strata, which are approximately horizontal, as well as by observations with the barometer and a hand level, to be about equal to that of Valentine, Neb., or about 2600 feet above the sea. The well was begun in the fall of 1895, and work was continued with considerable interruption until June, 1897. Samples have been taken every ten feet. The boring was done by a cable drill such as is used in drilling for oil, and circumstances are not favorable to exact measurement. From an examination of the samples preserved, together with a few statements given by the borers themselves, the following very general section is made:

Formation	Thickness—Feet	Depth—Feet
1. Mostly light colored, sandy clays, somewhat calcareous, with a few sand and gravel strata interspersed	375	375
2. Drab colored clays varying considerably in shade, hardness and amount of fine silicious matter, also in the amount of calcareous matter shown by effervescence	2000	2375
3. Mostly fine sand with occasional layers of drab colored shale, similar to that above	175	2550

Water was struck first at a depth of about 175 feet, which furnished a supply of cool and sweet water for use in running machinery, drinking, etc. At about 1650 feet the shale was moist and somewhat muddy. After the boring had been discontinued for a time water was found to stand within 600 feet of the top. After the sand was struck, water arose considerably, indicating the presence of the usual artesian supply, but of the exact height to which it arose, I have not been informed. The samples preserved will be carefully studied and reported on later, but that does not signify in this connection.

This well is noted for two or three things. First, it indicates the thickness of the Tertiary to be considerably less than would have been expected from observations made upon exposures further west. On the other hand the thickness of the Cretaceous shales, representing the Ft. Pierre, Niobrara and Ft. Benton groups surpasses considerably all estimates that have been made from exposures in the surrounding region to the east and north. Another point is the apparent absence of anything like chalkstone. Strata of limestone, two or three feet in thickness, were struck several times, but it resembled in character more the large lime concretions which abound in certain horizons in the shale. In this respect, however, it does not differ from any other borings further east.

This well attained a depth of 2500 feet in February, 1897, and owing to the exhaustion of funds the work was arrested. From the report of Mr. Darton in the 18th Annual of the United States Survey, we learn the following:

The water in the boring stood at 1140 feet below the surface when a depth of 1390 feet had been reached, in December, 1895.

When a depth of 1490 feet was reached the water rose slightly.

When the first sand was struck at about 1880 feet in the hard layer water rose to within 600 feet of the surface in February, 1896.

At 2165 feet there was a very open water-bearing sand rock which caused the water to rise 100 feet more.

In a bed of sandstone from 2292 to 2310 feet, more water was found without increase of head. Appropriation has been made to carry the boring clearly through the Dakota formation.

The following is the log of the well as given by Mr. Darton:

	Formation	Thickness—Feet	Depth—Feet
1.	Tertiary sand and clays	350	350
2.	Dark gray shale	1040	1390
3.	Light gray shales	160	1550
4.	Light gray shales, very calcareous, thin stratum		
5.	Light gray shale, in part calcareous	180	1730
6.	Dark shale	130	1860
7.	Sandstone, with water and hard limestone below	10	1870
8.	Hard sand rock, water rising to -600	10	1880
9.	Shale, dark below	40	1920
10.	Hard sandstone	10	1930
11.	Shale, black and soft above, light below	130	2060
12.	Soft shales, capped with thin layer of hard sand stone	15	2075
13.	Unknown	25	2100
14.	Sandstone, hard above with layer of shale and clay below	40	2140
15.	Soft shale	10	2150
16.	Porous rock	25	2175
17.	Unknown	35	2210
18.	Shale	30	2240
19.	Sandstones	50	2290
20.	Gray shale	2	2292
21.	Fine grain sandstones, with some shale and pyrites	210	2502

The elevation of the water in this well corresponds well with the increase of pressure toward the west and with the pressure obtained in the last Pierre well, in fact, the agreement is remarkable. This may lead us to the inference that the boring at Rosebud has probably reached the highest head attainable. If this be the case, there will be a considerable region south of White River lying in the Indian reservations where flowing wells cannot be obtained. The deeper valleys of the vicinity of the Rosebud well do not cut more than two or three hundred feet lower than the mouth of the well.

The Yankton Agency Well.—Arrangements were made with the agent and borers of this well, also, to keep a record and preserve specimens. The well is located at Greenwood about forty feet above the ordinary stage of the Missouri River. The report as given me both by the foreman, J. F. DeKay, under the employ of Mr. W. W. Swan, the contractor, and also officially by the agent, Capt. J. S. Smith, is as follows:

	Formation	Thickness—Feet	Depth—Feet
1.	Soil	1	
2.	Yellow clay	24	25
3.	Gray shale	19	44
4.	Blue shale	31	75
5.	Blue shale, with chalk nodules and gravel	16	91
6.	Yellow sand and gravel	23	114
7.	Gray greenwacke (conglomerate)	3	117
8.	Gray shale	6	123
9.	Gray lime and pyrites	21	144
10.	Sandy shale	34	178
	(From 144 to 150 water came in and rose to within 65 feet of the surface.)		
11.	Blue shale	21	199
12.	Black shale pyrites and lime shells	76	275
13.	Blue shale, tough	105	380
14.	Black shale, full of pyrites	40	420
15.	Brown sandy shale with thin streaks of lime	28	448
16.	Sand	420	421
	(Furnished water which flowed at 10 gallons an hour, was soft, temperature 56 degrees Far.)		
17.	Black shale	49	497
	(482 to 492, thin sand rock in the shale, increased the flow to 7 gallons per minute.)		
18.	Gray shale	3	500
19.	Black shale with thin pyrites and lime	31	531
20.	Gray shale	21	552
21.	Sand rock	4	556
	(Third flow.)		
22.	Gray shale	21	577
23.	Sand rock	4	561
	(The flow increased to 30 gallons per minute.)		
24.	Gray shale, pyrites and lime	62	623
25.	Sand Rock	10	673
	(Fifth flow, 70 degrees Far. Six inch pipe goes into hard rock below, 60 feet of the bottom perforated. The closed pressure was 119 pounds per sq. in.)		

The observation was made for only a short time. The pressure with 2¼ inch opening is 96 pounds; for 3.5 inch opening is 59 pounds. The pressure height would be equal to 1535 feet above the sea. No cap rock was found over the water strata.

The Crow Creek Well.—I have the following record of the well sunk at this Agency from the agent, Mr. Fred Treon, furnished by his secretary. I have not as yet ascertained the height of the well above the river, nor has the closed pressure been taken. Probably 30 feet would not be far out of the way for the first, making the altitude about 1400 feet.

	Formation	Thickness—Feet	Depth—Feet
1.	Loamy sand and gravel	38	38
2.	Fine dirty sand	5	43
3.	Fine gravel, mostly quartz	5	48
4.	Dark calcareous shale with fine mica grains	106	154
5.	Dark hard limestone	3	157
6.	Undermined, probably shale	95	252
7.	Dark calcareous shale, clay with some sand layers	183	435
	(First flow at 409 feet.)		
8.	Dark argillaceous fine greenish sandstone, micaceous and slightly effervescing with pyrite grains	265	700
9.	Fine grained pyrites	3	703
10.	Dark shaly calcereous clay with some layers of sand and pyrites	77	780
	(The main flow at 760 feet.)		

The Well at Cheyenne Agency.—Of this I have received no official report as yet. From a statement made by Dr. Charles McChesney, Indian agent at Rosebud, who was on the ground at the time of boring, I learned that water was struck at 1300 feet, that the mouth of the well is about "90 feet above the river," that the closed pressure was 135 pounds, that a six-inch pipe was sunk to 1000 feet, and below that a four-inch pipe was used. The temperature was 112 Far. The pressure height was nearly 1850 feet above the sea. We add from the Eighteenth Annual Report of the U. S. Geological Survey the following:

Log of Artesian Well at Cheyenne Agency.

	Formation	Thickness—Feet	Depth—Feet
1.	Yellowish gravelly clay	21	21
2.	Sand, boulders and shale fragments	5	26
3.	Shale, hard	14	40
4.	Blue shale, firm	240	280
5.	Blue shale, soft	110	390

6.	Black shale	95	485
7.	Sandy shale	15	500
8.	Gray shale	15	515
9.	Hard shale	60	575
10.	Dark gray shale	75	650
11.	Gas	50	700
12.	Black shale with occasional beds of hard sand rock	350	1050
13.	Blue shale	150	1200
14.	Dark gray shale, gas	111	1311
15.	Yellow lime rock, soft	16	1317
16.	White sand rock, flow	6	1323
17.	Brownish shale	14	1337

The Andes Lake Wells.—Two excellent wells have also been secured at Andes Lake. The following logs are taken from the 18th Annual of the U. S. Geological Survey:

Lake Andes Well No. 1.

	Formation	Thickness—Feet	Depth—Feet
1.	Yellow gravelly clay	20	20
2.	Blue clay and hardpan	25	45
3.	Sand and gravel	10	55
4.	Blue boulder	75	130
5.	Sand and gravel	33	163
6.	Black shale	17	180
7.	Blue shales with lime	85	265
8.	Lime rock	15	280
9.	Yellow sandy shale	65	335
10.	Gray shale	140	475
11.	Blue shale with lime	45	520
12.	Shelly rock lime	30	550
13.	Blue shale	65	615
14.	Sand rock, light color	18	623
15.	Blue shale with sand and pyrites	102	725
16.	Sand rock, light color	48	773
17.	Soapstone	2½	775

Lake Andes Well No. 2.

	Formation	Thickness—Feet	Depth—Feet
1.	Yellow gravelly clay	35	35
2.	Blue boulder clay	115	150
3.	Sand and gravel	50	200
4.	Hardpan and boulders	8	208
5.	Blue shale and lime rock	12	220
6.	Chalk Rock	17	237
7.	Black shale	19	256
8.	Yellow sand rock	30	286
9.	Yellow sandy shale	39	325
10.	Gray shale	145	470
11.	Blue shale, lime streaks	50	520
12.	Shelly lime rock	25	545

13.	Blue shale	70	615
14.	Sand, shale and slate	60	675
15.	Sand rock, shale streaks	55	730
16.	Sand rock	71	801
17.	Shale	1	802

The altitude of Lake Andes in 1884, according to railroad levels was 1518 A. T. The mouth of the wells is probably a little higher.

The more important facts connected with these tests wells are the following:

First, that the pressure, as has been noticed heretofore, further east is proved to increase strongly toward the west. It is probable that at all of these wells, except possibly the Yankton Agency well, the lowest stratum and highest pressure has not yet been struck. The point of special interest is the unusual thickness of the Cretaceous shale at Rosebud. This will be quite an obstacle, if it extends widely in the region south of White River. At the other points the shale has been much thinner.

SPRINGS PROBABLY DERIVED FROM THE ARTESIAN SUPPLY.

As has been shown by the wells at Chamberlain, the Missouri River has cut down within a few hundred feet of the upper water-bearing stratum. This with the great pressure and the yielding character of the overlying clays goes far to account for the breaking out of water along the channels of the larger streams. At Chamberlain, near the head of American Island, there are two springs which have been known for several years in which the water rises 12 to 15 feet higher than the ordinary stages of the stream. Moreover, the water has a different character and a higher temperature than that of the river. Further down, between the island and Oacoma, there are strong springs reported by those who are familiar with the region, as showing by clearer water at ordinary stages, and in winter by open places.

Similar facts have been reported to me by two or three parties as having been noticed a little below Ft. Randall in the channel of the Missouri River. I have been informed also by Mr. J. Q. Anderson that a spring of peculiar character has been noticed near Bull Creek, four miles south of White River and a little west of the Missouri, which is less confidently referred to this source.

At Olivet, on the east side of the James River, upon a wide bottom, there are two circular ponds in which the water stands ten to twelve feet above the ordinary stages of the James River. They are, perhaps, half a mile from the bluffs on the same side of the river. The larger one is 100 feet or more across and very deep, remaining open during the winter most of the time. An outlet has been cut from it which furnishes a constant flow to the river close by. By far the most satisfactory explanation of these ponds is, that they are supplied from the artesian strata which are not more than 200 feet below the surface.

THE PROBABLE WESTERN LIMIT OF THE ARTESIAN AREA.

As will be found from our previously given data, the pressure height or "head" at Belle Fourche is at least 3030. It may be considerable more. At Rapid City it is approximately 3200, with a possible variation of fifty feet or more either way. At Edgemont the altitude is about 3300. This indicates that the hydraulic gradient rises slightly to the south or is nearly on a level on that meridian. Moreover, it is so near the altitude of the points where the streams cross the Dakota formation, along the east border of the Hills, that it seems not improbable that at times water may be given out from the sandstone rather than absorbed into it. It seems not improbable, also, that wells near the Black Hills may vary much from time to time as to the water which they discharge, showing themselves more sensitive to local rainfall.

Further east, we have wells at Cheyenne Agency, Pierre and at Rosebud on nearly the same meridian, and the altitude to which the water rises is from 2000 to 2100 feet above the sea. Again it would appear that the slope of pressure declines a trifle toward the north. This would agree with the conception that the main supply of the water comes from the main range of the Rocky Mountains, which is nearer on the southwest. With these points as a guide, we are prepared to give approximately the western margin of the main artesian area of South Dakota. It would include, probably, along the valley of the Grand River at least as far west as the junction of the two branches in Wagner county. Along Moreau River as far as Rhinehart county, up the valley of the Big Cheyenne, as has already been shown, as far as Belle Fourche, up Bear Butte Creek nearly to the base of Bear Butte, up Bear Creek nearly to Grashull, up Rapid Creek to Rapid City, up Spring Creek to the railroad and Battle Creek nearly to Hermosa, up the South Fork of the Cheyenne to the Falls. As there are wide, high terraces along the Big Cheyenne, there are probably many square miles in that valley upon which flowing wells might be obtained.

The artesian area would probably include the valley of Bad River as far west as Big Cottonwood Creek, in Nowlin county. Wells could, doubtless, be obtained on White River as far west as Jackson county.

But most of the region south of White River, wide areas along the divides between White and Cheyenne and also between the tributaries coming from the Black Hills as well as along the divide between White and Bad Rivers, and between Bad River and Cheyenne are certainly too high to obtain flowing wells. Moreover, the high ridge between the Cheyenne and Moreau and the divide between the latter stream and the Grand River, together with an extensive region of the head waters of these streams, including the northwestern corner of the State would probably also fail to furnish flowing wells from the Dakota formation. In the last locality, however, a few flowing wells might be obtained from the Laramie.

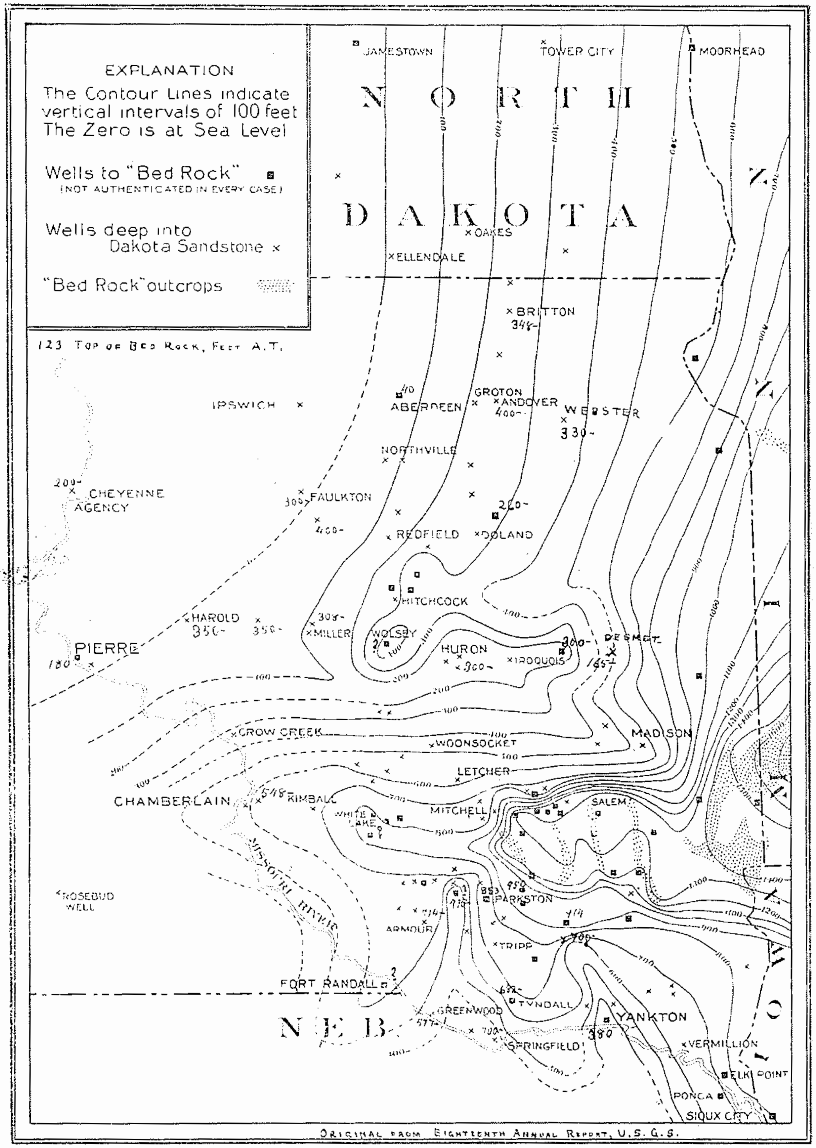
As has already been stated in connection with the Minnekahta boring, it seems not improbable that around the Black Hills and within their borders, except where the Archaen rocks are at the surface, water might be obtained from the Minnelusa sandstone and the Potsdam. Of course there would be no flows except at lower altitudes, but probably at higher levels than could be supplied from the Dakota. The distances to which these formations extend underneath the Dakota is not known except that they do not reach to the Missouri River.

The chance of striking bed rock is slight over the whole region west of the Missouri. As is shown by the uplift of Raw Hide Butte south of the Black Hills and by the disturbances in the Slim Buttes noted on page 62, and others which have recently been reported to me by Mr. Darton of the U. S. Geological Survey, as found south of Pine Ridge, we have reason to believe that the upper surface of the underlying crystalline rocks are in places quite uneven. But the well at Rosebud, and the borings at Buffalo Gap and other points near the Hills, all go to show that such rocks are probably at much greater depth than further east.

We have entirely insufficient data for any confident statement, but it seems probable that flowing wells may be obtained along the valleys of the Cheyenne and White Rivers, within the limits mentioned, by boring from 600 to 1000 feet below the level of the stream increasing toward the west until in proximity to the Black Hills. Elsewhere outside of the limits given and outside of the Black Hills, water will doubtless be obtained, but will necessarily be pumped from 100 to 600 or 700 feet, according to the altitude of the locality. Moreover it is probable that we shall find from these areas, as further east, much variation in the openness of the water-bearing rocks and the consequent readiness with which the water is given out.

DISCUSSION OF THE SURFACE OF BED ROCK.

We are glad to be able to furnish so complete and satisfactory a map of the general surface of the "bed rock," so far as has been determined in the eastern part of our State. By "bed rock" we mean the hard crystalline rock below which it is useless to seek artesian water. Nothing of Mr. Darton's map has been erased, but additional data have been added. From this it will appear that the bed rock is higher by nearly 200 feet at Pierre than Mr. Darton estimated. Also that the boring at DeSmet shows that bed rock, at that point, is much deeper than he represents, in fact, it presents a difficulty. We must suppose that there is there either an enclosed basin or else that there is a deep outlet from that point along some line that has not yet been discovered. It will be seen from the depths marked for the bottom of different wells that there is no clear evidence that the deep valley extends westward from that point. For example, the wells at Huron and Iroquois do not reach below 300 feet above the sea. The same may be said of wells about Andover and northward. It seems quite likely that the depression runs northward from DeSmet rather than westward. Mr. Darton, in the 18th Annual, expresses doubt of the occurrence of bed rock at Ft. Randall at the depth marked because of the deeper wells on both sides of it. The bed rock at White Lake is also in doubt, because Mr. Swan, who bored the wells, admits that the rock was similar to that struck at Scotland, before the quartzite was reached. Moreover, it is known, not only from borings, but also from strata exposed near Sioux City, that certain layers of the Dakota formation are intensely hard, rivaling the Sioux quartzite in toughness



CONTOUR MAP OF "BED-ROCK" SURFACE IN A PORTION OF THE DAKOTA ARTESIAN BASIN BY N H DARTON

Scale 0 5 10 20 40 80 Miles

AMENDED BY J. E. TODD, STATE GEOLOGIST, 1898.

and hardness. The cement, however, in all these cases, is calcareous instead of silicious. The peculiar depression leading southward in eastern Douglas county, seems to rest, mainly, on the depth of two or three wells east of Parkston. As the altitude of that region is in question, the existence of that peculiar depression is also somewhat doubtful.

From the granite ridge leading southwest past Hitchcock, it seems that the ancient eroded surface of the Archean rocks showed low ranges of granite approximately parallel with the axis of the quartzite area. The quartzite being in the form of a peninsula extended southwest past Mitchell, while the granite occupied the country further north. With this view, the granite ridge at Hitchcock, and possibly at Wolsey, would corespond roughly with the exposure of granite at Big Stone Lake.

Because there have been very few wells sunk west of the Missouri, it is perhaps idle to speculate upon the depth of bed rock in that region. We simply call attention to the fact that the Rosebud well reaches down within about 200 feet of sea level without striking bed rock, and that the well at Cheyenne Agency, which probably does not strike the lowest water-bearing stratum, is nearly on a level with the surface of the granite revealed in the deep well at Pierre, indicating that the bed rock is also deeper toward the north. It seems not improbable that the ridge of bed-rock may extend to the Black Hills, near the latitude of Chamberlain. The later submergence north of that line during the close of the Cretaceous and south of it toward the end of the Tertiary, suggest something of that sort.

From the dip of the rocks exposed and from the borings at Buffalo Gap, Edgemont and Ardmore, it appears that the slope of the surface of bed rock is much more abrupt around the Black Hills, than on the eastern edge of the artesian area. It is not improbable that 50 to 100 miles from the Hills the surface of bed rock may sink considerably below sea level and that the whole system of water-bearing strata may be correspondingly depressed.

J. E. Todd.

Varying Pressure in Artesian Wells.

Frequently, wells in the same locality give quite different pressures from the same stratum or "flow." When this is marked, there is little doubt that the wells showing lower or abnormal pressures have a subterranean leak because of imperfect construction.

Wells, generally, are perceptibly affected by variations in the pressure of the air. This is of course slight and not often noticed, but where a well has its mouth but little below its head, or pressure height, it may attract much attention. Wells so situated are known to flow more copiously shortly before a storm, or when the south wind blows, which usually brings low barometer. On the other hand, they are sluggish during a north wind and may stop entirely for a few hours when the barometer is unusually high. As cold weather brings denser air and higher barometer, some wells have a habit of stopping during the winter.

Another very interesting variation in pressure has been noticed in the southeastern part of the State in wells near the Missouri. When the river rises there is a corresponding rise of pressure in the wells. This is clear evidence that there is leakage from the stratum supplying the well into the bed of river adjacent. Greater depth produces greater pressure which hinders the leaking into the river and causes more water to escape through the well.

Again, the pressure varies, with years. In the spring of 1897 there was a general rise in the wells near Vermillion, but not so in 1898. Careful investigation is likely to show that this is due to greater precipitation or some other circumstance increasing absorption of water along the western margin of the Dakota formation.

Multiplying wells in a locality lowers the pressure, especially if they flow freely.

No cause of loss of pressure is more common than gradual filling with sand from below. We can easily understand how this would check the flow, but the closed pressure seems also distinctly lowered. It would seem that the molecular force of adhesion had some unusual or imperfectly understood effect under such conditions.

The Exploration of the White River Bad Lands in 1896.

Toward the end of June, 1896, a small party from the State University, consisting of the State Geologist and six of his students, namely, Ernest Eckert, Robert W. Ellis, Peter A. Jordan, Byron S. Payne, T. Mack Vinson and Elmer J. Wallace, started from Vermillion upon a geological reconnoissance through the southern portion of South Dakota. Not only was their aim to explore portions little known geologically, but also to make a beginning upon a State collection of the remarkable vertebrate fossils found in the White River Bad Lands. The means of transportation were two teams with covered wagons and the usual conveniences for camp life. Their course passed through the southern tier of counties from Vermillion to Rosebud Indian Agency, thence westward up the beautiful valley of the South Fork of the White River through Lugenbeel county, thence northwest across the divides and valleys of the White and Cheyenne Rivers to Hermosa. Delays of several days at Rosebud, Porcupine Creek and the noted fossil ground, Indian Draw, had accumulated over half a ton of fossils and other specimens which were shipped by rail from Hermosa. From thence the homeward trip was taken northeasterly across the Cheyenne and the well known trail between the Black Hills and Chamberlain which follows the divide between White and Bad Rivers. Short lateral trips were taken in the valleys of Indian Creek and Pass Creek. From Chamberlain, the party reached home by the most convenient route, without spending any time in exploration or study.

The party was provided with aneroid barometers, photographic apparatus and hand level. The whole work was in way of reconnoissance, rather than a careful geological study.

TOPOGRAPHIC NOTES.

The country traversed is quite different from the undulating plain which one finds in the latitude of central Nebraska. East of the Missouri River it shows the gently undulating topography, consisting of basins and swells, which characterizes a glaciated region. It lies mostly from 200 to 300 feet above the Missouri River, but there is a rough, high ridge north and northeast of Yankton, Turkey Ridge, and another high north and south ridge along the east branch of the Choteau Creek, running as far north as Tripp, and another, also, from the junction of the two Choteau Creeks northwest, at a distance of from three or four miles from the Missouri past Andes lake. These ridges raise their highest points from 250 to 350 feet above the previously mentioned plain. The ridge west of Choteau Creek, running parallel with the Missouri, declines southward with ravines and divides down to the level of a high terrace about 200 feet above the Missouri. This terrace occupies most of the angle in the Missouri east of Yankton Agency. Along some of the streams there are terraces at a lower level.

West of the Missouri much of the country is a table land. Beginning 450 to 500 feet above the Missouri near Greenwood and gradually rising westward so that in the longitude of Rosebud it averages more than 2750 feet; and west of Porcupine Creek, overlooking the White River, it may be estimated to be about 3500 feet. Upon this general level are elevated higher points usually in the form of flat topped buttes, which are more numerous along the principal divides. These are 150 to 200 feet higher than the before mentioned plain. A line of these extends westward from the Bijou Hills, continuing between the White River and its south fork. One of the more notable of the series is a prominent land-mark known as the Eagle's Nest. Beyond the head of the South Fork of White River, the higher level is less eroded and appears as a series of high head-lands, the northern end of the divides between the more prominent streams running north, as Porcupine Creek, Wounded Knee Creek, etc. Other remnants of this elevated plain are found in the buttes southwest of Bonesteel and a few others less prominent, though higher, west of the Keya Paha.

Between the White River and the Cheyenne, southeast of the Black Hills, the higher points though standing out as sharply sculptured buttes correspond more nearly to the general level than to the top of the series of buttes just mentioned. They are more uniform in altitude. West of the Cheyenne the country slopes quite rapidly from the outer base of the Black

Hills at an altitude of about 3500 feet toward the Cheyenne, descending in that distance several hundred feet. This marks the general altitude of the highest tables or divides. Into this the streams have cut valleys which show two or three marked terraces. Upon this feature I need not dwell, because it has been treated elsewhere.* So also the wonderful erosion of the Bad Land region between the White River and the Cheyenne.

From the standpoint of the so-called New Geology, we may describe the features already mentioned as representing the following base levels of erosion:

First, and highest, that of the original Miocene Plain formed from the filling up of the great fresh water lake of that age. This we believe to be represented quite closely by the summits of the buttes capping the divides south of White River, from Pine Ridge to the Bijou Hills.

Second, the Pliocene base level which corresponds approximately to the general level, sloping from 1700 feet near the Missouri to 3500 on the west. It seems never to have been perfected. This, we believe, to be the work of streams excavating the surface of the country, when the relative altitude of streams was some 400 or 500 feet higher than at present.

Third, the early Quaternary represented by the highest terraces along the streams flowing from the Black Hills into the Cheyenne and that of the divide between the Cheyenne and White Rivers, corresponding to the tops of Sheep and Cedar Mountains, the Great Wall, and of the most elevated buttes of the Bad Lands. This corresponds also with the very highest gravelly terraces shown along the White River, and the Missouri as far east as northern Knox County, Neb.

Fourth, the later Quaternary, corresponding to the principal terrace, or terraces (for it is in some cases subdivided) along the streams heading in the Black Hills, including especially the Cheyenne, and also seen along the White River and Missouri. This is believed, from its relation to the glacial deposits, to correspond to the earliest occupation of the outer moraine. Some of the lower bouldery terraces correspond probably to the times of later moraines.

Fifth, Recent, including the alluvial bottom lands of the present together with several lower and less bouldery terraces, found along the Missouri, Cheyenne and White rivers.

*Bulletin No. 1, page 122, South Dakota Geological Survey.

GEOLOGICAL NOTES.

The deposits traversed in this expedition, those exposed between Vermillion and Hermosa, include only the following formations, viz: The Dakota exposed only on the extreme west; the Colorado; the Montana; the Miocene, including the White River, which some count Oligocene, and Loup Fork; the Pliocene which may not be clearly recognized; the Pleistocene or Quaternary and the Recent. Of these, little need be said of the Dakota.

COLORADO.—Under this we include the Ft. Benton and Niobrara, which in this region are not very clearly separable from the Ft. Pierre. The Ft. Benton is only exposed on the outer slope of the Black Hills. The dip toward the east doubtless carries all that would properly be included under this head below the surface within a mile east of Hermosa.

The Niobrara does not show in conspicuous cliffs upon the west, but only as bluish or cream colored shale as shown on the south bank of Battle Creek southeast of Hermosa, and its upper portion not by continuous limestone strata, but in the form of great concretions, weathering to a cream and color showing hard angular fragments. These concretions are often a rod across and five or six feet in thickness. These are seen forming the top of a distinct shoulder south of Battle Creek about a mile and a half southeast of Hermosa. The estimates taken of the Niobrara as represented by these features at that point is about 200 feet. The horizon marked by these concretions dips sharply to the east and is soon below the level of the stream. In the eastern portion of our field the Niobrara appears along the Missouri River, forming conspicuous cliffs to the height of 80 to 100 feet above the river at Greenwood in nearly horizontal position, and therefore gradually sinking below the river toward the northwest. These cliffs are a conspicuous feature, (except where long exposed to the weather) as far east as St. Helena. They are more frequently prominent upon the right bank.

THE MONTANA.—This formation is represented by the Ft. Pierre group which lies conformably upon the upper surface of the Niobrara and is not easily distinguishable in outward appearance from some of the layers included in that formation, as well as in the Ft. Benton below. Upon the west this formation covers all the surface of the country, except upon the summit of the divides, as far east as the Cheyenne River. At the mouth of Battle Creek it constitutes the body of the high terraces upon the west side of the river, and rises upon the east side at Indian Draw to the height of about 150 feet above the stream. Its upper surface seems quite even, though as it marks a break in the geological series it has an eroded surface, and at a few points, beds of sand and gravel occur upon it, as though traces of local stream action during the interval between that epoch and the Miocene. It is the surface formation over almost the whole region between Bad River and White River, and a little south of the latter toward the east. The White River formation overlies it in patches, especially along the divide in Ziebach county. It extends up the Ponca River, and also up the Keya Paha to Raymond's.

Upon the east it forms the greater height of the bluffs along the Missouri River from the mouth of the Niobrara northward. At Greenwood its base is about eighty feet above the river and it rises quite distinctly to an altitude of more than 400 feet, presenting a thickness of at least 300 feet. Along the bluffs of the Missouri its upper surface is obscured by the sliding of slopes, and because the Tertiary above resembles it somewhat in appearance. Around Fairfax it must rise about 450 feet above the river, while at Bonesteel on nearly the same level, Tertiary loam and sands fill a basin in the Pierre about 100 feet deep. Its upper surface is quite uneven. This formation has been often described and we need not speak of it here, except to say it is almost everywhere a dark colored clay or shale. It exhibits few fossils, except in the vicinity of large concretions which occur abundantly at two or three horizons. The vertebrae and other bones of large marine reptiles not infrequently occur in this formation. Its estimated thickness upon the west may be stated as about 500 feet. Its exposed surface in the latitude of Greenwood upon the east is less than 350 feet, while at the Bijou Hills it is probably near 500 feet. It extends underneath the drift quite continuously as far east as the James River, and in patches into northwestern Iowa, where it has been noted near Hawarden by Mr. H. F. Bain.

From the borings in the deep well northeast of Rosebud Agency the combined thickness of the Ft. Benton and Niobrara, and Ft. Pierre amounts to over 1700 feet. At that point the distinction between these three formations is not very evident.

The second member of the Montana formation, the Fox Hills group, seems not to be represented either at the west or east side of the State in this latitude. Also, during the Laramie epoch, this region was probably dry land.

THE MIOCENE, INCLUDING THE OLIGOCENE.—No traces have been found of Eocene deposits, except the following. As before stated, there occur under the White River beds at several points, beds of sand and gravel apparently of fluviatile origin, including pebbles from the Black Hills. Along Indian Draw and at some other points toward the Western side of the Tertiary area this horizon is water-bearing, affording feeble springs usually of an alkaline character. This would go to show that during the Eocene the whole region was undergoing erosion.

THE WHITE RIVER FORMATION.—This includes the light colored clays, marls, and interstratified gravel and sand deposits which appear above the Cretaceous upon the divides between the western tributaries of the Cheyenne, and occupies most of the country between the Cheyenne and White Rivers where their course is northward, and about the head of Bad River in Ziebach county. As it extends eastward its upper surface declines more rapidly than the general surface of the country and it begins to be overlaid by the next formation, the Loup Fork, to the east and south of White River. Outliers of this formation occur north of the White River as far as Peno Creek, in Ziebach county. Further east they are confined mostly to the summit of the divide north of and near White River through Jackson county.

After reading Dr. Hayden's descriptions, and the discussion of them in Bulletin No. 84, U. S. Geological Survey, I find myself unable to satisfactorily fit the description to the formations observed during our trip. Especially is it doubtful where he intended to divide the White River from the Loup Fork formation. Not having the assistance of study of the fossils, and judging more from the stratigraphical relations, as far as they can be determined in a hasty survey, I have considered the summit of the loess-like loam, in some cases of a light cream color and elsewhere of a reddish tint, as the dividing line between the White River and Loup Fork. This decision was strengthened by the discovery, as it was supposed, of volcanic ashes in the upper portion of the loam. That fact would harmonize with the clearly marked disturbances, noted in the Slim Buttes, as recorded in a preceding paper of this volume. As is stated elsewhere, this ash stratum has not been positively shown to belong to that horizon. Our whole classification is to be considered provisional.

This formation is not easily divided into divisions worthy the name. Dr. Hayden recognized five, of which the Titanotherium and Oreodon beds were the lowest two. The former of these consists of massive light gray marly clay, usually weathering in rounded rick-like ridges, traversed occasionally by horizontal strata of shades varying from white to light purple, also locally containing irregular strata of coarse sand with pebbles. In some cases these strata are cemented by silica forming a very firm conglomerate, but more frequently they are but slightly consolidated. These characters hold quite generally for the lower 80 to 125 feet, not only upon the western border where they are shown, as at Indian draw, and Sage Creek, but along the northern border of the formation, as near Cottonwood Creek, Pass Creek, and north of Stearns. Characteristic views are shown in Plates XII and XIV.

The Oreodon beds are more uniformly stratified, consisting of marly clay, impure limestone and coarse sandstone. The marly clay presents frequently very beautiful stratification of clay in various colors, showing vertical thicknesses of from six inches to three feet. The colors are usually of subdued tints of pink, cream color, purplish and yellow. These have a thickness near Indian Draw of 250 feet or more. This member appears to be thinner toward the east and north.

Above the Oreodon beds are the Protoceras beds, as they have been called from their characteristic fossil, a horned carnivore. They are not markedly different from other beds below them. We did not differentiate them in the field. The lower beds of the White River group are often traversed with veins or dikes. They were found especially prominent near the mouth of Porcupine Creek. They are rarely over a foot wide and are filled with quartz of different colors, with satin spar, or in some cases with fine grained sandstone showing signs of being forced up from below.

A prominent member above these has a thickness of about 200 feet along the divide between Porcupine Creek and Wounded Knee. It erodes more like the loess, being quite easily excavated by rapid streams, and the banks receding by vertical cleavage, so that miniature canyons are frequently formed in it. It constitutes the highest points east of the White River in Washington county and most of the surface in the valley of the South Fork of the White River as far east as the eastern line of the Pine Ridge Reservation.

It readily becomes sculptured into gently convex surfaces with shallow basins intervening, some of them of considerable extent and containing water as in western Lugenbeel county. These basins, as have been pointed out by Mr. G. K. Gilbert of similar formations elsewhere in the west, are quite clearly traceable to the action of winds. The prevalent direction of their longer axes is toward the northwest, from which comes the strong and more prevalent winds during the seasons when the surface is dry and most easily excavated. This material closely resembles the loess which shows similar shallow basins in eastern Nebraska. The upper surface of this cream-colored loess-like silt is quite distinctly marked where it underlies the sandy and less consolidated Loup Fork beds and frequently stands in cliff-like form on the banks of the larger streams. It is easily traceable as far east as Rosebud, where it forms massive cliffs rising to the height of fifty or sixty feet above Rosebud Creek. It seems possible also that this same upper member passes as far east as the Missouri near Greenwood though only rarely exposed. There is found there a light colored marly clay appearing above the Ft. Pierre, and rising to the summit of the bluffs, representing a thickness in patches of 80 to 100 feet. Moreover, it is frequently penetrated in the digging of wells, as at Bonesteel. At that point, the town well is said to pass through ninety feet of white, marly silt, locally known as "magnesia." Water is there found in the layer of sand which appears attended with springs at a corresponding depth in the ravine upon the north.

The extension of it to the Missouri is far from being established. The beds there may be Loup Fork entirely.

THE LOUP FORK.—The later Miocene is represented by the Loup Fork formation. Its most prominent development is further south in Nebraska. It consists mainly of strata of sand and loam with occasional layers of white fresh water limestone and clay. The sand beds are often locally hardened by the infiltration of silica into hard splintery greenish quartzite.

This seems to be easily acted upon by the surrounding water, and the surface is apt to lose its translucent character so as to resemble mortar. At several horizons there are compact strata of limestone from six inches to four or five feet in thickness. These usually abound in fresh-water shells. We have been unable to secure a representative section of this formation during the work of the past summer. Judging from the distribution of the sand which is believed to mainly derived from this formation we find it extending over the surface of the White River formation in the form of detached buttes and sand hills as far west as Porcupine Creek. It evidently is thinner toward the west and in the vicinity of Rosebud it is estimated to be 100 to 150 feet in thickness. Eastward the hard flinty sandstone which is by far the most durable member of the formation has been traced at several points as follows:

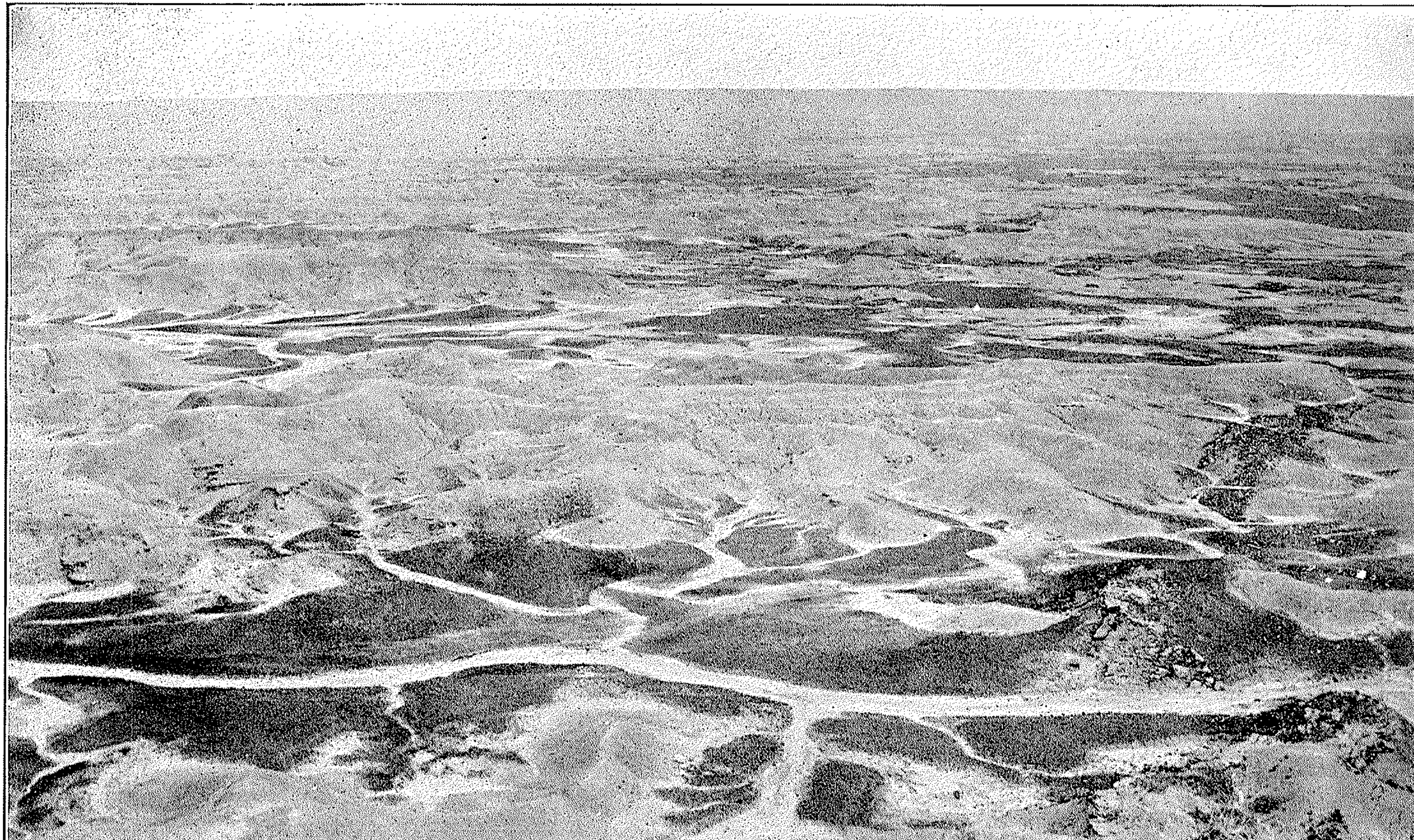
The first known to the writer and most clearly shown is the heavy sandstone capping of the Bijou Hills, east of the Missouri River in Brule county. Westward from this point is a series of similar flat-topped buttes elongated east to west, and it is probable that this formation will be found capping the buttes marking that divide as far west as Eagle's Nest. This rock is found capping Medicine Butte in Lyman county, also a butte five or six miles northeast of Greenwood, in Charles Mix county. It is found covering more or less the Tertiary on the west bank of the Missouri most of the way from White River to the south line of the State. It is found nearly as far east as Aten, Neb. It is often a conglomerate and the patches of pebbles, often found on top of hills in Gregory county and further east, may be considered results of the weathering of remnants of this stratum.

Limestone strata usually of fine-grained magnesian character, weathering white, containing fresh water shells, were found capping a butte a few miles east of Red Butte in Lyman county and north of Young's in Lugenbeel county, so also on Rock Ridge Creek and the Keya Paha in Tripp county, also southwest of Rosebud Agency near the Grand Crossing of the South Fork of the White River. They may be the product of local lakes among the sand hills of that ancient time.

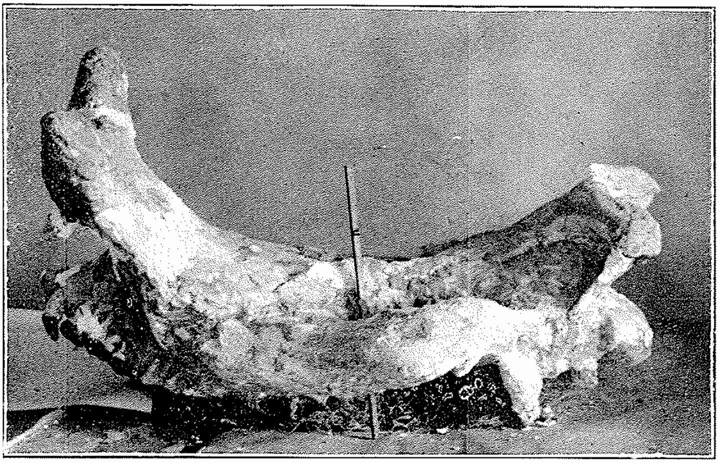
THE LIFE OF THE MIOCENE.—So much has been written concerning the wonderful fossils and strange animals belonging to the Miocene Age, that little need be said here. We will simply speak of some of the specimens obtained by our expedition.

The fossils collected have not been, as yet, sufficiently studied to make a careful report. However, a few of the more valuable and interesting may be briefly described. The largest and most characteristic fossil is the skull of an ancient animal known as the Titanotherium, called by some Brontotherium. The skull found is about 2½ feet in length and nearly as much in breadth. Like the skull of a rhinoceros, it suggests the form of a saddle, but instead of one horn above the nose there is a pair side by side, several inches in length. The back part of the skull rises in a transverse crest so that one is strongly reminded of a large side-saddle. The Titanotherium resembled the elephant in size of body, but was not so tall. Unlike it, instead of a proboscis, it probably only had a somewhat flexible nose, like a tapir. Also like that animal, its heavy short legs were tipped with four toes on the front feet and three upon the hind feet. Its habits not improbably were like those of the rhinoceros. It might be spoken of as an enormous hog. It had no prominent canine teeth and its food was probably largely of a vegetable nature. Its remains in some localities, as in Indian Draw, are very abundant. At certain levels in the clay several acres may sometimes be quite thickly strewn with the fragments of their bones. The more solid portions like the leg bones and the firmer parts of the skull may sometimes be found intact. In Plate XIII, 1, we furnish a view of the specimen obtained by our party, of a complete skull. There were several species of these animals, some of them considerably larger than the specimen figured. Plate XII gives a characteristic view of the Titanotherium beds in Indian Draw. It shows the alternation of clay hills and grass flats with water courses brimming with water after every shower, for very little water is absorbed by the ground.

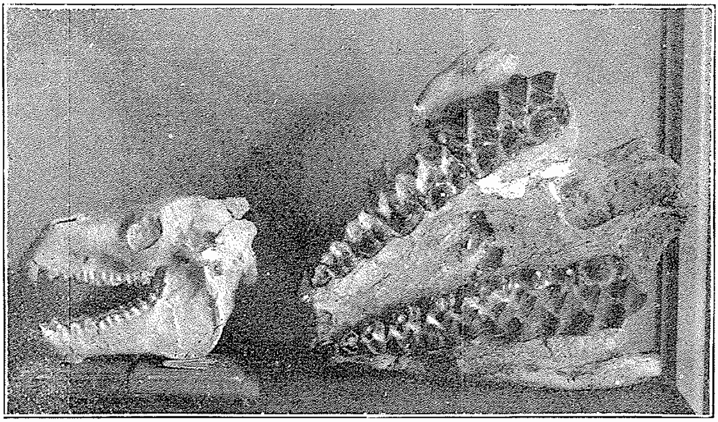
In beds above the Titanotherium beds numerous fossils of Oreodons and Turtles are found. The Turtles are sometimes of enormous size. Specimens were collected from a few inches in length to nearly three feet. The Oreodons, of which there were several species, were numerous, combining the characters of a hog and deer. Many of them were about the size of a sheep. Plate XIII, 2, shows a skull which we obtained near Porcupine Creek.



View northeast from Central Butte across Indian Draw.



1. Titanotherium Skull obtained by the Expedition of 1896. Now in the University Museum.



2. Oreodon Major and Titanotherium Giganteum Skulls. Museum of University of South Dakota.

The Rodents were found represented in still higher beds by four or five species, none of them very large; the Carnivora by as many more, and of these none were found larger than a dog. In one place a nearly complete skeleton of that size was found, although in small fragments. Incomplete specimens were also found of a species of rhinoceros, of a camel and of one of the ancestors of the horse, about the size of a sheep.

In Loup Fork beds, which overlie the White River, specimens of marsh plants and of fresh water shells were found in great numbers in some localities, also the imperfectly preserved bones of mammoths and mastodons.

THE PLIOCENE.—The Pliocene Age has left its impress upon the region, so far as has yet been ascertained, mainly in the erosion which took place at that time. At the close of the Miocene we may safely conclude that the surface of the region was a lacustrine plain, extending across the State at a level corresponding with the altitude of the higher points now preserved in the top of the Bijou Hills, the buttes in Gregory county, and the summit of the buttes capping the divides between the various branches of White River from the south; also some of the divides separating the streams east of the Black Hills. During the Pliocene the present drainage system in general was outlined and such streams as the White, Cheyenne, and their principal tributaries, began to flow in the depressions of the original Miocene plain, probably not remotely distinct from their present courses. That there was, however, some difference, is indicated by the distribution of the pebbles and boulders derived from the Black Hills. As before hinted, these are found covering the divides between the Cheyenne and White Rivers, so that they abound along the latter stream at high levels as far east as its mouth, and even along the Missouri at altitudes 500 feet or more above its present bed. For example, several pebbles of trachyte closely resembling if not identical with that found in the Black Hills, were found four or five miles west of Bonesteel, in Gregory county, upon the general upland level over 500 feet above the Missouri.

We have already referred to the capping of the higher buttes between the Cheyenne and White Rivers with boulder formation. The highest of these probably dates from the early Pliocene. This would indicate that at that time the South Fork of the Cheyenne had not yet turned northward, but had flowed eastward into the original White River. It is hoped that further investigation will discover traces of Pliocene accumulations containing remains similar to those of the Equus beds further south. The period was one of erosion and probably of gradual differential elevation westward.

At first, besides the streams from the Black Hills flowing eastward to the White River, it seems probable that the South Fork of the White River flowed eastward to the point where it now turns north, and then by a wide valley that is still traceable made its way southeast into the Minnechadusa and Niobrara. The valley of this stream above that point is wider and shallower than below that point. It seems not improbable that the lower course of this branch was first a separate stream like others flowing into the White River, and that it cut a ravine far enough south to pass through the divide and tap the original South Fork of the White River, so presenting a case of "river piracy." Sometime during the Pliocene the streams, as a result of the gradual elevation of the region together with the copious discharge of water from the Black Hills and consequent more rapid erosion on the west, opened the South Fork of the Cheyenne in its present position. At the end of the Pliocene we believe we have evidences for concluding that the Cheyenne and White Rivers with their principal tributaries were flowing along their present courses at levels corresponding to their highest bouldery terraces.

VOLCANIC ASH STRATUM.—As we have already referred to the volcanic ash stratum in Lungenbeel Co. on the South Fork of White River, we may here give a possible different interpretation. Before, we had considered it as probably dividing the White River and Loup Fork epochs. This is clearly the case, if it be found that the stratum extends underneath the heavy deposits of Loup Fork beds at a distance from the stream. Such we deem probable from the fact that such have been found in the upper strata of Cedar and Sheep Mountains at apparently corresponding horizons in the White River formation. If, on the other hand, the beds are found to be confined to the comparatively narrow area of the stream valley, it may be easily inferred that the deposit was made in a lake-like expanse of the stream during the Pliocene epoch probably previous to the diversion of it from its southeasterly course, northward into the White River. From the haste naturally attending a reconnoisance, these significant points were not determined. We have received information from Professor F. W. Cragin, of Colorado Springs, urging the probability that this volcanic ash stratum is of a similar character and similar age to one found in Colorado, the Pearlette ash,* which he judges was deposited in late Pliocene time.

THE PLIOCENE DEPOSITS.—To this epoch belongs the glacial drift of the eastern portion of the State as well as the large deposits of aqueous drift around the Black Hills and down the principal streams.

THE GLACIAL DRIFT.—Upon this we need dwell but briefly here because of our fuller treatment of it in Bulletin No. 1. We may simply note a few points freshly impressed by the recent trip. The area north of Bon Homme and east of Snatch Creek was found much higher than the ordinary elevation of the plain further west. Moreover, the chalkstone cliffs which appear north of Running Water and at Springfield are discontinued from the mouth of Snatch Creek eastward nearly to the east line of Bon Homme county, or to the high ridge which we have interpreted to be a portion of the first moraine. The significance of this fact is perplexing. It would seem that the chalkstone had been removed previous to the advent of the ice sheet, or, in other words, that the Missouri at this point had either formerly extended northward along the line of Snatch Creek to the James River, or, it had formed a sharp curve to the north and back into the present channel. Present knowledge seems on the whole to favor the view that its preglacial course was up Snatch Creek past the low lands near Tabor and thence east along the Rhine valley and lower Beaver Creek to the James River.

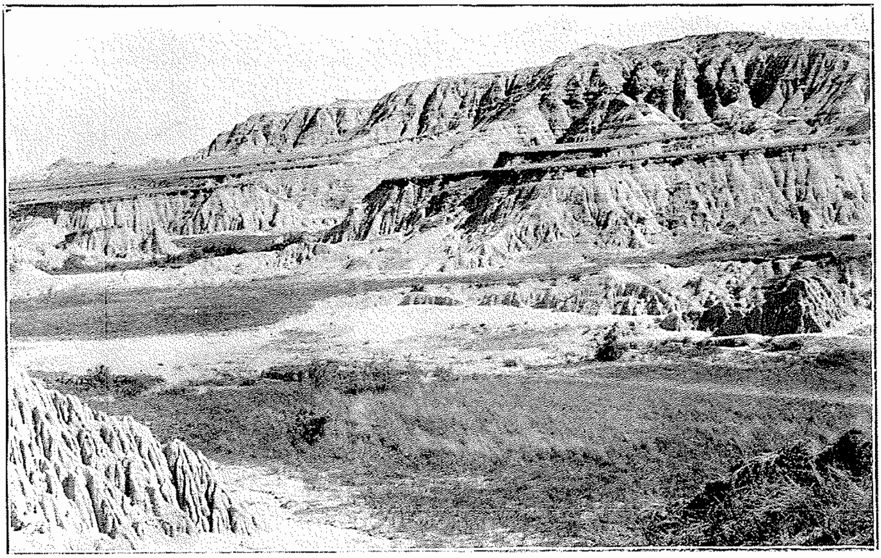
The more important suggestion arising from this fact, however, is the probable deep erosion of the valley of this stream previous to the occupation of the first moraine. It would seem that the Niobrara, like the Big Sioux and Vermillion, was flowing at much less altitude at that time than were the White and Cheyenne rivers further north. And this is readily explained by the quartzite ledge crossing the James River near Mitchell, and forming a barrier and higher base level.

*Colorado College Studies, Vol. 6, p. 54.

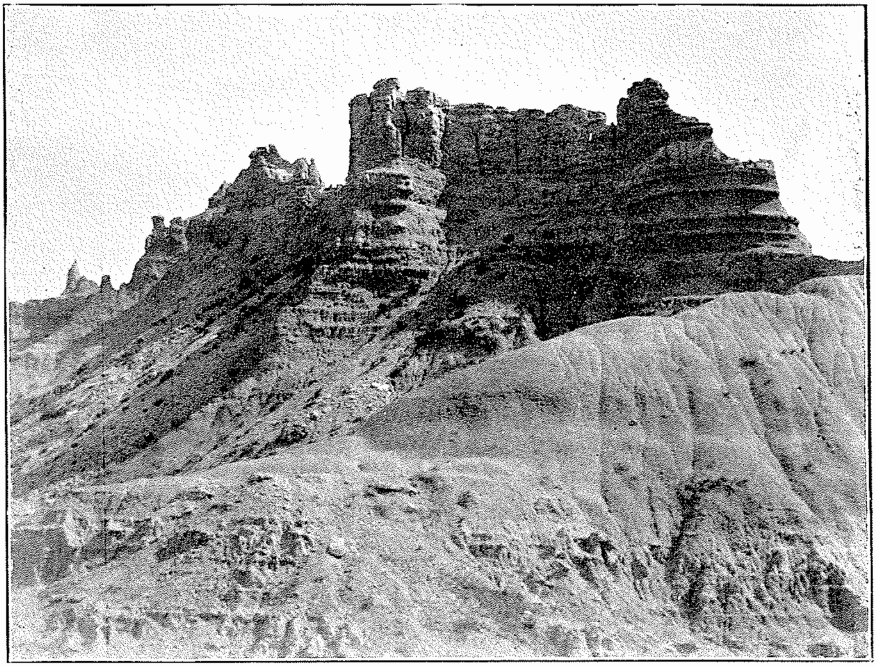
The western limit of the drift as before published, was corroborated by the observation of this season. No northern boulders were found on the uplands west of Greenwood, south of the Missouri River. Approaching Chamberlain from the west, the first boulders were found in the vicinity of Red Butte, and were sparsely scattered upon the Tertiary beds showing in elevated points several miles further east, while the lower spaces between, though of clayey character rarely exhibited any distinct trace of drift.

During the Pleistocene while the ice sheet was changing the main channel of drainage from the James River valley to that of the present Missouri, its western tributaries were, for a time at least, flowing at a level corresponding with the previous epoch. And because of a probably greater rain-fall in the Black Hills, and the surrounding region, they were larger than at present and frequently overflowed. To this stage we would attribute the better preserved and more stony terraces along these streams. This is most evident along the Cheyenne, and next in prominence is the White River, while the Bad River, owing to its small basin and failure to draw from elevated localities has this feature much less prominently developed. We believe the 400 foot terrace which appears at Ft. Randall should be referred to the early portion of the Pleistocene epoch. Before the close of the ice age, and probably before the recession of the ice from the second moraine, the Missouri has cut down to within 150 to 200 feet of its present level. The cutting through of the divide at Bijou Hills had the effect upon the Cheyenne and White Rivers to rapidly deepen their channels.

Recent Formations.—Under this head we would include the alluvial terraces along the streams, the accumulation of soils in certain relatively lower areas. We need not enter into details concerning different streams because our observations have been but fragmentary. The Cheyenne and White rivers, both of them, have flat plains which present space enough for small farms. They are sometimes half a mile in width. This flat plain is covered with light colored clay and silt derived from the Tertiary beds and Cretaceous beds, the latter being more influential along the Cheyenne. This flat plain is from five to fifteen feet above the stream. Where it is low, it is frequently overflowed by the sudden freshets which characterize



1. Along the "Great Wall," east of Sage Creek, showing erosion and rearrangement of "Bad Land" marls, looking south.



2. Castellated Butte near Pass Creek, Jackson County.

and apparently quite durable. Blocks a foot or two in length and breadth and one or two feet in thickness may be quite easily obtained from the tops of some of the buttes along the South Fork of the White River as well as some in the Bad Lands toward the base of the White River formation. A stratum of four or five feet in thickness, composed of several layers, was found near the top of the Great Wall about the head of Sage Creek. Blocks of large size may be found beneath the surface. The stone has a sonorous quality resembling "clinkstone." Some of the layers have the appearance of scoria, from the abundance of clay pebbles which were originally deposited with the lime, which, when exposed to the weather, are easily dissolved away.

CLAYS.—The Ft. Pierre and numerous layers of the Tertiary beds are quite pure clay, the former containing considerably carbonaceous and ferruginous matter, the latter usually very little of either. There has yet been no careful examination of the clays of these formations. It is not improbable that certain beds may be found of considerable value.

SATIN SPAR.—We have already referred in our general description to the occurrence of vertical veins traversing the White River clays near Porcupine Creek and at other points. These are frequently filled with gypsum, not in sufficient quantities to be of use as cement, but possibly of some value for small ornamental work because of its finely fibrous character.

BARITE.—The occurrence of sulphate of barita was noted first by Dr. Hayden at Rosebud and Pass Creek. Frequent concretions of this material were found at certain levels in the upper part of the White River formation. Some of them were fine-grained, and resembling in appearance ordinary calcareous concretions. Others showed distinct tabular crystals. None of them were more than two or three inches in diameter. No workable beds, therefore, have been found, though search for such should be encouraged. The occurrence of Barite has also been observed in some of the large concretions found in the upper part of the Ft. Pierre formation. This is usually in the form of beautiful wine-colored crystals, mingled with those of calcite in the crevices of large biscuit-shaped concretions.

SAPPHIRINE.—Some of the calcedony found in the veins of the lower part of the Tertiary is colored a delicate blue tint, the lighter of it sky blue, and some a medium indigo blue. At a few points, fragments of this are quite abundant. None have been observed more than three-fourths of an inch in thickness, and most have been more or less cracked by exposure to the weather. A sample was submitted to Mr. George F. Kunz, who pronounced it Sapphirine, and expresses the opinion that specimens without flaws would be of some value to jewelers. He mentions the Ural Mountains as another locality where this mineral is found.

GRASSES.—Large areas of the Bad Lands, namely, the region between White River and the Cheyenne river, together with detached patches, extending as far east as the mouth of the South Branch of White River, are entirely barren of vegetation. The rest of the region traversed is covered mainly with short grasses, including "alkali grass," Agrotyron, and "buffalo grass," Bouteloua and Buchloe, and in some areas much grass of several other and larger species. None of the region is heavily grassed except some of the lake beds where there is not too much alkali and alluvial bottom lands along the principal streams. The whole region west of the Missouri is subject to long, hot, dry seasons and the rain-fall is less than twenty inches. The grasses are considered very nutritious and will support considerable pasturage, though the danger of overpasturage is great. Upon the uplands we saw extensive areas where the grass had not grown that season, and the accumulated growth of several seasons was not sufficient to hide the surface of the ground. In one place we saw the remarkable exhibition of a man drawing a mower, with a hay rake attached behind, with the same team, and in some regions it was impossible to obtain hay even in that way. It should be stated, however, that this was in the region pastured not only by cattle, but by sheep also. In the Bad Land region the horizontal surfaces, both those capping the buttes and also the alluvial fans at the foot of the buttes, are usually covered with a thick growth of short grass, so that the Bad Lands afford considerable pasture, and much shelter for stock during stormy weather. Plates XII and XIV exhibit these features.

TREES.—Along the smaller streams over the Tertiary areas, there are usually found cotton-woods of a stunted, gnarled character, in the distance scarcely distinguishable from dwarf oaks. Along the larger streams cotton-woods, elms and ashes grow to medium size, and are found in groves. Upon the sides of the buttes in the Bad Lands red cedars are common wherever sufficient moisture has been retained by land-slides or other stoppage of water ways. Considerable groves of these are found at a number of points. They rarely exceed a height of 15 or 18 feet, though some have a diameter of 2 feet. Upon the buttes composed of the Loup Fork and Upper White River formations, groves of red pine are frequently found.

WATER.—As we have already stated, the region is not very well watered. The sands of the Loup Fork have a tendency to retain the rainfall and to discharge it in springs along the small streams traversing that area. So also the upper loamy member of White River Formation retains considerable moisture, but not sufficient to bring it to the surface except toward its base, where the more impenetrable clays of the lower member tend to bring it to the surface. Between the White River formation and the Fort Pierre clays are also quite limited beds of sand and sandy clay, which afford at some points considerable water, though usually much contaminated with the mineral salts of the underlying strata. The Fort Pierre formation is not known to afford water at any point. The alluvial capping of terraces rarely furnishes enough water to produce permanent springs. We have, therefore, from the Loup Fork formation a number of clear copious streams of small size like the Keya Paha and the South Fork of the White River. These rarely fail. The main supply of the White River and Cheyenne may also be attributed to this source mainly.

The water rises from the upper portion of the White River, in most of the southern tributaries of White River. Along the middle portion of these streams as they are marked upon the map, are most of the Indian settlements, like Oak Creek, Medicine Root, Porcupine Creek. This is due to the occurrence at that point of quite permanent springs of water due to the cause explained above. Above those points the ravines are deep and narrow, affording escape to the sudden rainfall, but not containing permanent water. Below the points mentioned the streams are also largely intermittent, for the streams are frequently of insufficient supply to carry them through to the White River. Toward the east the waters may be brought to the surface by the underlying Fort Pierre clays, but in that case are apt to be more or less alkaline. The horizons already enumerated are also the main supply of water in wells. It is probable that water may be obtained in this way much more frequently than is now done, for the Indians rarely dig wells, but depend upon springs and water holes for their supply. The water hitherto mentioned is clear and sweet. In the Bad Land areas the rains are unable to penetrate the ground; and during the rainy season, and often all the year, the water is found in basin-like holes in the ravines and stream channels. Usually it is so mixed with the white clay from the Bad Land that it resembles dirty milk; nor does this clay settle. The common expression is that "it settles toward the top," and oftentimes it does accumulate as a scum which is cut by mud cracks somewhat as curd in sour milk. It is not precipitated by boiling, nor by ordinary influences, but it is said that milk will do it.

The amount of clay in these basins varies often in the same creek bed, some basins being probably more than half clay, others having very much the same appearance yet being comparatively pure water. The water in these basins is sweet and wholesome with the exception of clay. The water of the White River, during the ordinary stages below the Bad Lands has a similar character. Above that point it is quite clear, and in winter time the same is true of it throughout its course. The Cheyenne River is clear when at low stage which, however, rarely occurs. It is generally a very muddy stream. The effort to irrigate with the water of White River at a number of points has failed on account of the abundance of fine mud, which not only rapidly fills up the channels but seals the pores of the soil. So intimate is the mixture of this clay with the water that when wells are dug in sandbars along the stream the water appearing in them has the same milky appearance as in the main stream. The surest way of obtaining clear water is to dig close to the bank on the lower side of a promontory, separating two members of a horseshoe bend. In that case the water which percolates from the upper member of the bend to the lower is usually sufficiently filtered to be clear.

J. E. Todd.

INDEX.

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ERRATA.

Page 18, line 11, Barite for "Baryta."
Page 55, line 1, Calbick for "Calbrick."
Page 70, next to last line, 150 for "250."
Page 75, line 33, Laccolite for "Iaccolite."
Page 79, line 31, Halysites for "Halycites."

Page 107, later report is that the Cheyenne agency well is about 40 feet above the river or 1540 A. T. The pressure at first was 187 pounds per square inch, but in four days rose to 205. Much gas comes from the depth of 650. Temperature 80 degrees F. Water similar to that at Pierre.

Page 109, line 7, Pleistocene for "Pliocene."
Page 133, line 14, Agropyron for "Agrotyron."