

SOUTH DAKOTA GEOLOGICAL SURVEY
BULLETIN NO. 3.
J. E. TODD, STATE GEOLOGIST

MINERAL RESOURCES OF SOUTH DAKOTA

INCLUDING

MINERAL WEALTH OF THE BLACK HILLS

BY CLEOPHAS C. O'HARRA

AND

MINERAL BUILDING MATERIAL, FUELS
AND WATERS OF SOUTH DAKOTA

WITH PRODUCTION FOR 1900

BY JAMES E. TODD

Regents of Education.

NAME.	RESIDENCE.
F. A. Spafford, Pres.	Flandreau
Lewis M. Hough	Sturgis
M. F. Greeley	Gary
Ivan W. Goodner	Pierre
R. M. Slocum	Mound City

COMMITTEE ON GEOLOGICAL SURVEY.

F. A. Spafford	Ivan W. Goodner
----------------	-----------------

Personnel of the Survey.

J. E. Todd, State Geologist	Vermilion
C. C. O'Harra, Assistant Geologist	Rapid City
D. A. Saunders, Assistant in Botany	Brookings
C. P. Lommen, Assistant in Zoölogy	Vermilion

Letter of Transmittal.

OFFICE OF SOUTH DAKOTA GEOLOGICAL SURVEY,
VERMILLION, S. D., June 1, 1902.

SIR: I have the honor to present herewith for publication two papers exhibiting our present knowledge of the Mineral Resources of South Dakota. It is hoped that they may prove timely and valuable.

The metalliferous ores of the Black Hills, their distribution and the history of their development, as presented by Professor O'Harra, may well increase the pride of our citizens for our commonwealth.

Yours very respectfully,

J. E. TODD,
State Geologist.

HON. FREDERICK A. SPAFFORD,
President of Regents of Education.

Contents.

Letter of Transmittal	iv
Preface	vii
The Mineral Wealth of the Black Hills—	
Introductory	1
General Geology	2
Historical Review	6
Mineral Products	11
Gold	11
Vein Quartz Ores, 12. Auriferous Pyrite Veins, 15.	
Auriferous Dikes, Slate Breccias and Fissure Veins, 16.	
Impregnated Zones, 18. Cement Ores, 23. Cambrian	
Siliceous Ores, 29. Carboniferous Siliceous Ores, 41.	
Placer Deposits, 45. Tailings, 50. Methods of Treat-	
ment, 50. Output, 51. Future Prospects, 52.	
Copper	53
Iron	57
Manganese	59
Silver and Lead	60
Tin	62
Tungsten	67
Graphite	72
Mica	72
Spodumene	75
Miscellaneous Minerals	77
Resume of Mineral Production	78
Conclusion	79
Mineral Building Materials, Fuels and Waters—	
Introduction	81
Geological Formations	81
Building Stone	82
Granite, 83. Porphyries, 84. Quartzites, 84. Marble, 88.	
Glacial Boulders, 89. Limestones, 89. Lithographic Lime-	
stone, 93. Chalkstone, 93. Sandstone, 94.	
Cements and Clays	98
Cements, 99. Clays, 101. Fullers' Earth, 107. Volcanic	
Ash, 108. Sand and Gravel, 109.	
Mineral Fuels	110
Coal, 110. Lignite, 111. Peat, 113. Gas, 114. Petroleum, 119.	
Mineral Waters	121
General Summary for 1900	129
Index	131

Illustrations.

Plate No.		Opp. Page.
1.	Custer on French Creek	1
2.	The Holy Terror and Keystone Mines, Keystone.....	9
3.	The Uncle Sam Mine, Hoist and Mill, Perry.....	9
4.	Part of One of the Homestake Open Cuts, Lead.....	17
5.	Lead City.....	17
6.	Blacktail Gulch, Gayville.....	25
7.	Ruby Basin, looking west from Sugar Loaf Hill.....	25
8.	Porphyry Dikes in Algonkian Slates	33
9.	Cambrian Quartzite with Intercalated Porphyry Resting on Algonkian Slates.....	33
10.	Porphyry Needles at Top of Johnston's Peak	33
11.	Middle Cambrian Shales and Sandstones, Deadwood.....	41
12.	Stewart Mine on Lower Quartzite, near Terry	41
13.	Deadwood	49
14.	The Golden Reward Smelter, Deadwood.....	57
15.	Homestake Mills, Hoists and Open Cuts, Lead.....	57
16.	The Kildonan Chlorination Plant and Deposit of Home- stake Tailings.....	57
17.	The Cleopatra Mine and Cyanide Plant	57
18.	The Etta Mine near Keystone.....	65
19.	The Hidden Fortune Mine near Lead.....	65
20.	The McMackin Mine near Custer.....	77
21.	Spodumene Crystals, Etta mine, near Keystone.....	77
22.	Marble Quarry near Custer.....	81
23.	Quarry of Lowe & Handley, East Sioux Falls	89
24.	Evans Quarry, five miles east of Hot Springs	93
25.	Burke's Quarry near Odell, looking northwest.....	93
26.	a. Elm Creek Quarry in Jurassic Sandstone.....	
	b. Gypsum Layers, one mile north of Hot Springs.....	97
27.	a. Works of the Hot Springs Plaster Co., Hot Springs.....	
	b. Artesian Well Furnishing Both Hard and Soft Water....	97
28.	Works of the Western Portland Cement Co., Yankton.....	105
29.	a. Brick Plant of C. A. Marshall near Rapid City.....	
	b. Beds of Fire Clay Southwest of Rapid City	113
30.	a. Lithographic Stone Ten Miles West of Custer.....	
	b. Fullers' Earth Northeast of Fairburn	121
31.	South End of North Cave Hills, showing lignite beds.....	129
Figure No.		On Page
1.	Section Showing Relations of "Cement" Mines.....	26
2.	Section Through Faulted Body of Siliceous Ore.....	33
3.	Section Through Tornado Shaft, Terry.....	35
4.	Ore Following Joints in Cleopatra Mine.....	44

Preface.

The more liberal appropriation made by the last legislature encouraged the State Geologist to attempt a more complete presentation of our present knowledge of the mineral resources of the State.

Prof. C. C. O'Harra, of the School of Mines, who has done valuable work on the Maryland Geological Survey, and who was favorably situated for the work by his position and location, was engaged to examine and make such report as he should be able in one season on the ores and associated minerals of the Black Hills, while the State Geologist, by correspondence and a short work in the field, undertook to gather statistics and general facts concerning mineral building materials, fuels and waters of the State.

Much has been gathered, also, concerning artesian wells, with the thought of including at least some general conclusions concerning them in this report; but space has not been found, and, besides, it has been concluded that the whole had better be postponed for a future bulletin, to be devoted exclusively to the water resources of the State.

Meanwhile, for the service of those particularly interested in that subject, we would call attention not only to the papers of Mr. N. H. Darton on the artesian waters of the Dakotas in the Seventeenth and Eighteenth Annuals of the U. S. Geological Survey, to which we have referred before, but to one by the same gentleman on the Geology and Water Resources of the Southern Black Hills, in the Twenty-first Annual, Part IV, of the same Survey, and to No. 34 of the Irrigation and Water Supply papers of the same Survey, prepared by the State Geologist, which gives a simple description of water supplies in half a square degree including most of Hutchinson and Turner counties, S. D. Other similar publications are soon to be issued from the same source covering areas farther north in the James River Valley.

Attention is called, also, to an important paper in the Twenty-first Annual, Part III, of the U. S. Survey, by Dr. T. A. Jaggar, on the Laccolites (igneous rocks) of the Black Hills, which gives much light on the arrangement of rocks intimately connected with ore deposits.

It is by the co-operation of the School of Mines that we have been able to present so many illustrations; and Prof. O'Harra's paper has been published separately as Bulletin No. 6 of the School of Mines series. Copies may be obtained by addressing President R. L. Slagle, Rapid City.

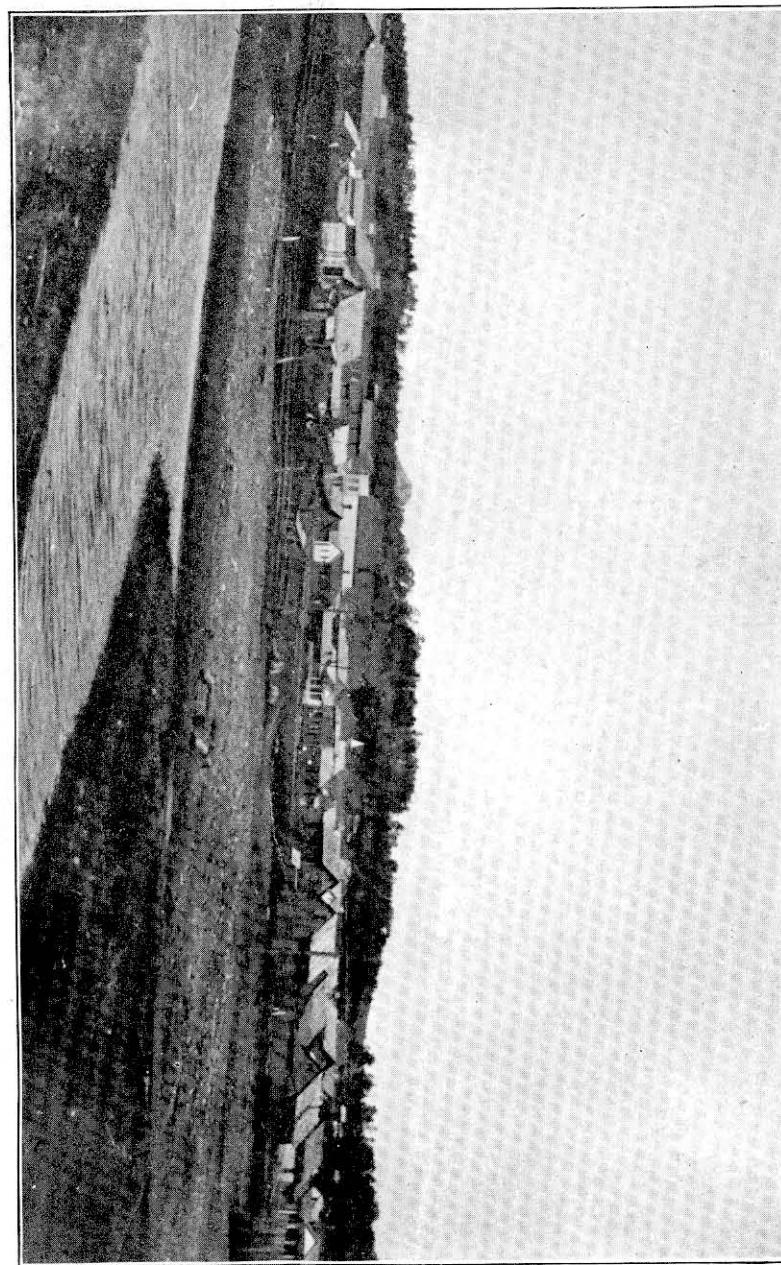
In the preparation of the papers in this bulletin there has been an effort to visit representative mines and quarries in every district, and to interpret carefully the information received from others in the light of personal observation, so far as time and funds would permit.

The hearty co-operation everywhere of owners and employes, and of other public spirited citizens, has greatly assisted in the success of the work. We have endeavored to give due credit for such service, particularly where valuable information has been afforded, as well as for much information gained from the published reports of other and more fully equipped students of the region; but perhaps we have inadvertently omitted some, and hence would make this general acknowledgment.

It was hoped that a complete summary of the mineral production of the State for the year 1900 could be constructed, but in the case of mines this has been found impracticable.

It is hoped that hereafter the Survey will have annual or biennial reports from all parties concerned, so that regular reports of our mineral production by years may be published. Such co-operation will not only be of much value to the citizens of the State, but will increase our credit elsewhere.

J. E. T.



Gold first discovered in the Black Hills in placer diggings near logs at corner of fence.
CUSTER, ON FRENCH CREEK.

THE MINERAL WEALTH OF THE BLACK HILLS.

By Cleophas C. O'Harra.

Introductory.

The first quarter century of active mining operations in the Black Hills has little more than closed. Considerable prospecting was done within the region in 1875, but operations of a permanent character did not begin until the opening of the following year. From an isolated and practically unknown, mountainous, forest-clad island in the midst of a vast treeless plain, and within the confines of a great Indian reservation, the Black Hills region has during its brief history become one of the most important precious metal producers of the United States. Railways have brought the region to the threshold of older communities, beautiful scenery peculiar to the country annually attracts its thousands; permanent homes, prosperous towns and productive ranches prevail, and mining facilities are in many ways unsurpassed. Gold found throughout the region, but obtained mainly from the northern Hills, is pre-eminently the chief mineral product, a total of approximately one hundred million dollars having been obtained during the past twenty-six years. Silver has been of importance in the annual output, while other ores and minerals already productive or capable of production add much to the variety of the mining interests and not a little to the mineral wealth of the region.

General Geology.

The Black Hills region is one of peculiar geologic interest. Separated from the Rocky Mountains, to the west and southwest, by a distance of less than one hundred fifty miles, it possesses many of the features of that great uplift. By virtue of its isolated position, the simple structural features of the region and the many excellent rock exposures, its history may be interpreted with a considerable degree of ease.

The Hills are situated within the forks of the Cheyenne river, on the boundary line between South Dakota and Wyoming, a much larger portion being within the borders of South Dakota. Structurally, the region is an elliptical quaquaversal uplift, the more distinct features of which cover an area about one hundred miles long and fifty miles wide, the longer axis approximately coinciding with the meridian except in the northern portion where the general direction is to the northwest.

The prominent topographic features are a high central basin of granite and metamorphic rocks of Algonkian age surrounded in a concentric manner by a prominent infacing escarpment of massive white Carboniferous limestone, a wide depression in the red Triassic shales, and a high rim of Cretaceous hog-back ridges or foot-hills. In the northern Hills post-Cretaceous intrusive rocks have greatly modified the general topography, and in not a few instances have formed prominent landmarks. Harney Peak, the culminating point of Harney granite range in the southern Hills and the highest point within the uplift, reaches an altitude of 7,216 feet. The surrounding limestone escarpment rises high above much of the central portion and considerable areas of the plateau along the western side closely approach the height of Harney Peak. The mean altitude of the plains surrounding the Hills is little more than 3000 feet. The average elevation within the hog-back ridges is approximately 5000 feet.

The rocks of the Black Hills show a wide range in age and character. Within the crystalline nucleus are pre-Cambrian granites, amphibolites, schists, slates, phyllites, and quartzites. Beyond this nucleus are limestones, sandstones, shales, and conglomerates representing a nearly complete sequence from Cambrian to Laramie. Extensive overlaps of Tertiary deposits are also present. Silurian and Devonian rocks seem to be present in only a few localities and are nowhere of importance. In the northern Hills there are porphyries, rhyolites, phonolites, dacites, tonalites and vogesites. The various sedimentary rocks have recently received careful study under the direction of the United States Geological Survey. The following section by Mr. N. H. Darton shows their age and general character: *

Generalized Section in the Black Hills Region.

Formation.	Character.	Average Thickness—Feet.	Age.
Laramie	Massive sandstone and shale	2,500	Cretaceous
Fox Hills	Sandstone and shale	250—500	do
Pierre shale	Dark-gray shale	1,200	do
Niobrara	Chalk and calcareous shale	225	do
Benton Group:—			
Carlile formation	Gray shales with thin sandstones, limestones, and concretionary layers	500—750	do
Greenhorn limes'ne	Impure slabby limestone	50	do
Graneros shale	Dark shale with lenses of massive sandstone in its lower part at some places	900	do
Dakota sandstone	Massive buff sandstone	35—150	do
Fuson	Very fine-grained sandstone and massive shale. White to purple color	30—100	do
Minnewasta limes'ne	Gray limestone	0—30	do
Lakota	Massive buff sandstone, with some intercolated sha. e.	200—350	do
Beulah shale	Pale grayish-green shale	0—150	Jurassic
Unkpapa sandstone	Massive sandstone: white, purple, red, buff	0—250	do
Sundance	Dark-drab shales and buff sandstones; massive red sandstone at base	60—400	do
Spearfish	Red sandy shales with gypsum bed	350—500	Triassic
Minnekahta limes'ne	Thin-bedded gray limestone	30—50	Permian
Opeche	Red slabby sandstone and sandy shale	90—130	Permian?
Minnelusa	Sandstones, mainly buff and red; in greater part calcareous. Some thin limestone included	400—450	Carbonifer's
Pahasapa limestone	Massive gray limestone	250—500	do
Englewood limes'ne	Pink slabby limestone	25	do
Deadwood	Red-brown quartzite and sandstone, locally conglomeratic, partly massive	4—150	Cambrian

* Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming. U. S. Geological Survey, Twenty-first Annual Report, Part IV, Hydrography, 1901, p. 593. [In order to complete this for the whole Black Hills there should be inserted between the Deadwood sandstone and the Englewood limestone 30 to 80 feet of buff, sandy limestone overlaid by about 25 feet of greenish shales, the former probably Trenton, the latter possibly Devonian. The limestone is 30 feet about Deadwood, but thickens westward to 80 feet or more in Spearfish canyon. These have not been noted further south.—J.E.T.]

In addition to the above named formations and to the pre-Cambrian and Tertiary rocks already mentioned, Pleistocene deposits of various kinds occur widely distributed over the surface of the region. Some of these, as well as certain of the older formations, on account of their economic interest, will be described more fully in subsequent pages.

The Black Hills region is drained by the Cheyenne river and its tributaries. Two main branches, the Belle Fourche and the South Fork, almost completely encircle the Hills and wholly isolate them from other systems of drainage. These encircling arms send radiating streams toward the more elevated portions of the uplift, the high western limestone plateau being the main divide. It is of particular importance that, although the Black Hills are surrounded by a semi-arid plain, the Hills themselves have a considerable rainfall, and many of the streams within the more elevated portions flow without intermittence. The annual rainfall varies widely. Near the foot-hills, as observed by the U.S. weather station at Rapid, it averages 16.71 inches. At Deadwood, situated further within the Hills, it is about 28.5 inches, and this is perhaps a fair average for the areas in which the more extensive mining operations are carried on.

The probable geological history of the Hills is briefly as follows:* In Algonkian time the schists and quartzites were deposited as sediments derived from land lying apparently either to the west or to the northeast of the position now occupied by the Hills. Later these original sediments were cut by basic eruptives, at which time more or less metamorphism and folding were produced. Subsequent to this action the sedimentary rocks, as well as the basic eruptives, were ramified by quartz veins, many of which are gold-bearing. Following the eruption of the basic rocks and after most or all of the gold-bearing quartz veins were formed, extensive granite intrusions occurred. Apparently at the time of the intrusion of the basic eruptives the slaty

* Many authors have written on this subject. For the latest and most complete discussion of post-Algonkian conditions available at this writing, the reader is referred to the following: Darton, N. H. Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming. U. S. Geological Survey, Twenty-first Annual Report, Part IV, Hydrography, 1901.

cleavage was produced and approximately co-incident with the granite intrusions the crystalline schists were developed. At some time during the middle or latter part of the Algonkian period, the sea shallowed and the land, rising above the sea as an island, reached a considerable height. The rocks thus brought under the influence of erosive agents supplied much or all of the sediments which make up the Cambrian strata.

Little is known of the conditions during Silurian and Devonian time, rocks of these periods being absent in the southern portion of the uplift and very scantily represented in the northern portion. Deep water prevailed during the early part of the Carboniferous period and, although the sea subsequently shallowed, apparently little or no land area existed near the region until after the period closed. The Triassic red beds, with their included widely distributed lenses of gypsum, following the extensive deposition of the nearly pure Permian limestone, indicate a considerable uplift and general shallowing of the sea. The shales, sandstones, and impure limestones of the Jurassic, show considerable oscillation and, on the whole, further shallowing of the sea. The Cretaceous rocks, including as they do a great series of diversified strata, represent several changes of conditions. In general, it may be said that fairly shallow seas existed in the early and later portions of the period while during much of the intervening time deep waters prevailed.

Near the beginning of Tertiary time great disturbances took place. The region was lifted quite above the sea and deeply trenched by outflowing streams. Sea conditions disappeared, leaving the land partially or wholly surrounded by a considerable body of water in the form of a lake. Approximately co-incident with these changes the post-Cretaceous igneous rocks of the northern Hills were intruded among the sedimentaries, and by their subsequent denudation and degradation added their portion of sediment to the surrounding lake. The lake then disappeared, and upon its dry bed the modern streams have trenched their way. Concerning this and subsequent activity, in

view of the too frequent lack of appreciation of the work performed by streams, I cannot do better than quote from Prof. Newton: "The streams that had been transporting detritus from the Hills and casting it into the lake now found their way to the rivers and transferred their burdens to them. Little by little, but continuously, they have eaten away the substance of the Hills ever since. The canyons they have cut, and which appeal to our eyes as marvelous monuments of their industry, are the least of their results. Since their labor began they have demolished and removed one-half of the entire mass of the uplift. Modest and feeble as they seem, it is their ambition patiently to toil on until no vestige of the Hills remains."*

Historical Review.

The existence of valuable gold deposits in the Black Hills was first made known to the world in 1875. Certain stories, still current, indicate that some of the Sioux Indians and a few white men knew of the presence of gold here several years prior to this time, but nothing definite can be learned as to the actual facts. The earliest authentic account of its finding dates from July 27, 1874, at which time Mr. H. N. Ross and Mr. W. T. McKay, miners accompanying the expedition of General Custer, found small quantities of the precious metal in the bed of French Creek in what was then called Elkhorn prairie, now known as Custer park, the exact locality of the find being within the present town of Custer between Washington and Custer avenues where crossed by Ninth street.† Plate I. gives a view of the locality. In this view the exact place of discovery is shown to be some distance from the creek bed, the creek having been turned out of its former course by the railroad, which runs near. Owing to the rapid movements of the expedition, no thorough prospecting could be

* Report on the Geology and Resources of the Black Hills of Dakota, p. 222.

† Date and locality given by Mr. Ross, who now resides in Custer, and by whom the old diggings were pointed out to the writer. In this connection see also the following: Ludlow, William. Report of a Reconnaissance of the Black Hills of Dakota, Made in the summer of 1874. Washington, 1875, pp. 13 and 14.

done, and, although gold was observed in several localities, no definite idea was gained as to the extent or value of the deposit.

The report that gold had been found, although greatly exaggerated, quickly aroused much excitement among the frontiersmen. As a result, only a few weeks after the Custer expedition a party entering the Hills for the purpose of settlement reached French creek, and on Dec. 23, 1874, the date of their arrival, found gold about three miles below the present site of Custer, near what is known in Black Hills history as The Stockade, a structure built by the party soon after their arrival, for protection from Indians. The party did much prospecting in this vicinity during the winter, opening several quartz ledges within the park and sinking pits in the gravel bars along the streams, but were compelled by the military to leave the Hills early in the spring. Little gold had been found, and the mineral wealth of the region still continued veiled in mystery.*

The Black Hills country was not then open to settlement, the area being at that time included within the reservation held by the Sioux Indians. The government made strenuous efforts to prevent prospectors from entering, and the Indians were continuously upon the lookout for trespassers, but this seems only to have intensified the desire to explore and appropriate the country. As a result of this interest, and as a possible solution of certain frontier difficulties, the government in the early part of the year 1875 organized a special survey for the purpose of learning definitely whether or not the mineral and other resources of the region were such as to warrant its purchase from the Indians for settlement. Prof. Walter P. Jenney was appointed geologist in charge, with Mr. Henry Newton as associate geologist. The expedition reached the Hills in May, and shortly afterward established the fact beyond doubt that gold existed in the Hills in considerable quantity.

It is worthy of note that the first authentic published statement of the finding of gold in the Black Hills is given

* Tallent, Annie D. The Black Hills; or, The Last Hunting Ground of the Dakotas, 1899. p. 713.

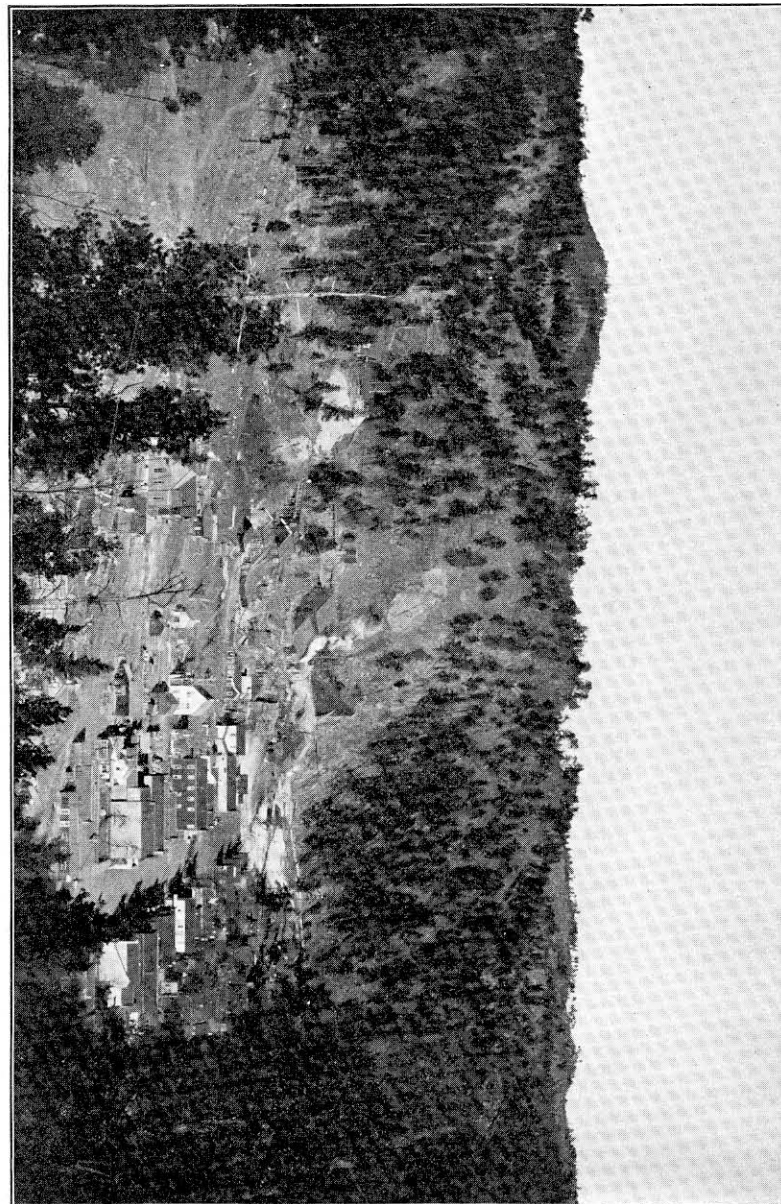
in a letter written by Prof. Jenney to the Hon. E. P. Smith, Commissioner of Indian Affairs, Washington, D. C. The letter, dated Camp on French Creek, near Harney Peak, June 17, 1875, was first published in the Mining and Engineering Journal. It was included later in Prof. Jenney's official report to the Commissioner of Indian Affairs, published in 1876 and again in the Report on the Geology and Resources of the Black Hills, 1880.*

The gold to which Prof. Jenney referred was found June 12, 1875, on the north bend of Castle creek in terraces or bars of quartz gravel and subsequently southward to French creek. Following this, much prospecting of an unsatisfactory nature was done along French creek, but nearly a month later important discoveries northeast of Harney peak in the placer deposits of Spring and Rapid creeks caused a rush in that direction, this being the first real stampede in connection with the Black Hills gold excitement. By this time several hundred prospectors had succeeded in gaining access to the region, and of this number more than one hundred staked out claims on Spring creek and proceeded to pan the gold.

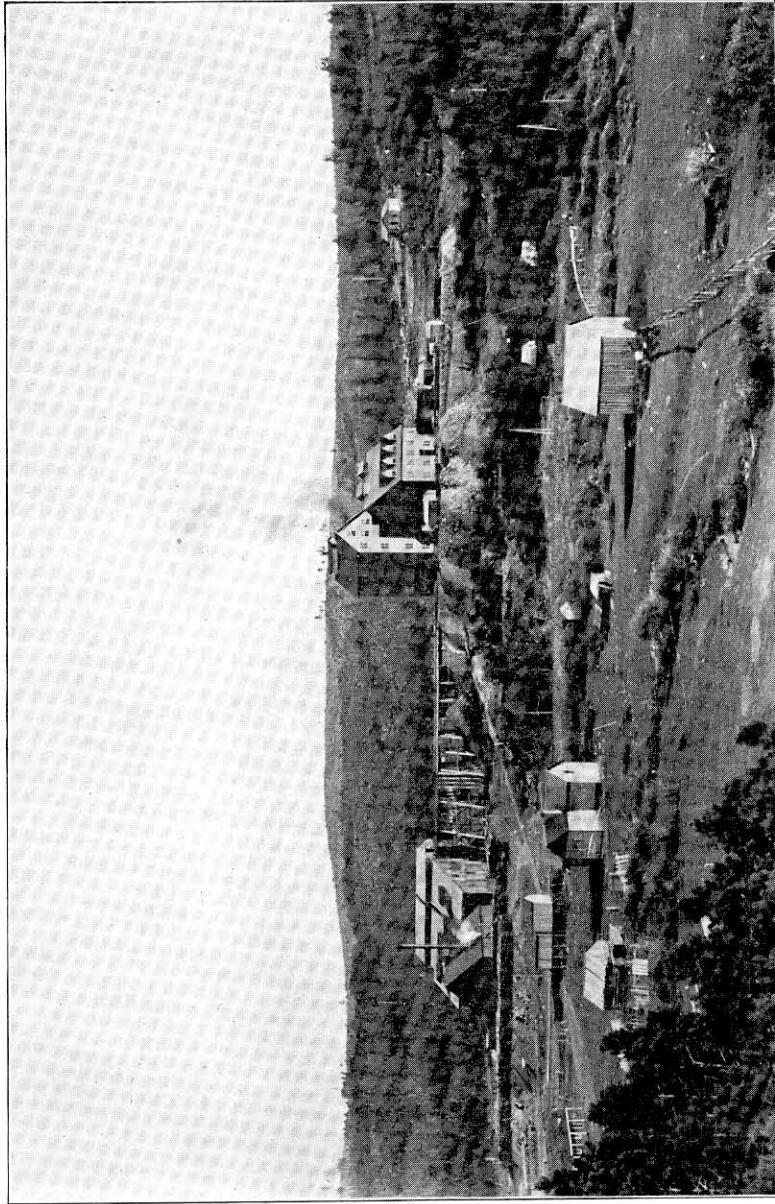
Prof. Jenney and his corps of miners continued their investigations throughout the summer, assisted in no little degree by the prospectors who had entered the Hills contrary to the regulations governing the reservation. French creek and Castle creek received the most attention, although considerable prospecting was done along nearly all of the more important streams within the Hills. The work was carried on principally with reference to stream gravels, but observations were made also upon rock in place. The results of these observations indicated no rich deposits such as have since been the cause of so much interest and excitement in the region, but were such as to give promise of good returns for careful work in many parts of the Hills.

The fact being therefore established that the Black Hills region was of much greater value for mining purposes than

* Report on the Geology and Resources of the Black Hills of Dakota with Atlas. By Henry Newton, E. M., and Walter P. Jenney, E. M., 1880, p. 566.



THE HOLY TERROR AND KEYSTONE MINES, KEYSTONE.
The Keystone mill in the rear on the right, the Holy Terror hoist above on the left.



THE UNCLE SAM MINE, HOIST AND MILL AT PERRY.

it could ever be to the Indians, the government at once entered into negotiations for the purchase of this part of the reservation. The negotiations were for a time unsuccessful, the Sioux war intervening, but the transfer was finally accomplished, and the region was opened for legal settlement Feb. 28, 1877. The Indians received the purchase price of four and one-half million dollars. Prior to the date of the President's proclamation permitting settlement and legal holding of land, proper titles could not be acquired, but under such arrangements as miners find it necessary to adopt in new countries, claims were laid out, controlled and worked. Owing to the practical impossibility of preventing the entrance of prospectors, the government in the latter part of 1875 withdrew all opposition to immigration to the Hills, and at the same time began to withhold much of its protection. As a result, Indian depredations became frequent, and lawlessness and disorder were common. People eager to gain some of the reported fabulous wealth continued to hurry to the region, so that before the President's proclamation was issued a number of mining camps and towns had been established and the aggregate population had reached several thousand.

In the fall of 1875 a small party from the southern portion of the Hills prospected northward along the head waters of various streams, and, reaching Deadwood gulch in the northern Hills in November, located what is known as Discovery claim a little below the mouth of Blacktail gulch. Some indifferent prospecting had been done in this vicinity during the preceding August, but it was not until near the close of December that rich deposits were found. Prospecting was continued during the winter months in this and neighboring gulches in what is now known as Lawrence county, and in the spring extremely profitable placer mining began. Previous to this time incoming parties had made Custer park in the southern Hills their first objective point, but with the discovery of the rich placers of the Deadwood region the northern Hills at once gained supremacy. The discovery a few weeks later of the rich conglomerate ores and of the great impregnated zone,

known as the Homestake Belt, indicated the permanent wealth of that part of the Hills, and during each of the twenty-six years since that time Lawrence county alone has far surpassed all of the remainder of the Hills in the production of gold.

Other facts in connection with the history of the region are of interest, but for these the reader is referred to subsequent pages, in which the development of the various deposits is reviewed. One feature, however, in the advancement of the region needs to be mentioned here, namely, the construction of railroads.

For ten years after the discovery of gold the Black Hills had no railway facilities of any kind. Mills were freighted long distances (generally from Bismarck, North Dakota; Cheyenne, Wyoming; or Sydney, Nebraska), and such ore as demanded treatment outside of the Hills had to bear the expense of a similar haulage.

In November, 1885, the Fremont, Elkhorn and Missouri Valley railway of the North-Western System reached Buffalo Gap near the southern edge of the Hills. In December, 1890, it entered Deadwood. Five weeks later the Burlington railway also entered Deadwood, and thus healthy competition in ore transportation began. A little before this, in 1890, the inter-urban narrow-gauge line connecting Deadwood and Lead was constructed and put in operation. Much of the Black Hills and Fort Pierre narrow-gauge road connecting Lead and Piedmont had been built earlier, but it was constructed for the particular convenience of the Homestake company, and for several years its chief use was in the transportation of timbers and fuel from the forest to the mine. In 1901 this road was purchased by the Burlington.

Soon after reaching Deadwood the Fremont, Elkhorn and Missouri Valley and the Burlington extended branch lines to the mines near Ruby basin, Bald mountain, Portland and Crown Hill, the Burlington descending into Spearfish canyon and going on to Spearfish. At this writing the two roads are extending their main lines into Lead, and the Burlington is entering Galena. Thus the northern Hills are favored with excellent railway facilities, and to

this fact is largely due the opening up of many important mines. The central and southern Hills are not so well supplied, but the construction of a branch line to Keystone by the Burlington three years ago from its main line at Hill City has partially relieved the demand.

Mineral Products.

The mineral products discussed in this paper may be conveniently arranged as follows:

METALLIC—	NON-METALLIC—
Gold	Graphite
Copper	Mica
Iron	Spodumene
Manganese	
Silver and Lead	MISCELLANEOUS.
Tin	
Tungsten	

Of these the metallic products will be treated first. The members of each group follow one another in alphabetic order, with the exception of gold, which by reason of its enormously greater importance is given first.

GOLD.

Classification of Black Hills Gold Ores:

- A. Ores occurring within the Algonkian rocks.
 1. In quartz veins.
 2. In veins of auriferous pyrite.
 3. In igneous dikes, sheets, etc.
 4. In slate breccias.
 5. In fissure veins.
 6. In mineralized zones.
- B. Ores occurring within the Cambrian rocks.
 7. In the basal conglomerate—"cement" ores.
 8. In slates, sandstones and quartzites—"siliceous" ores.
- C. Ores occurring within the Carboniferous rocks.
 9. In brecciated "verticals" in limestones—"siliceous" ores.
 10. In massive limestone—"lime-siliceous" ores.
- D. Ores within the Pleistocene deposits.
 11. In high level bars—"dry" placers.
 12. In present stream beds—"wet" placers.

In the treatment of the above divisions numbers 3, 4 and 5 are discussed together, likewise numbers 9 and 10 and numbers 11 and 12.

THE VEIN QUARTZ ORES.—The gold-bearing quartz veins are found chiefly in the central and southern Hills in Pennington and Custer counties. Lawrence county in the northern Hills includes some valuable quartz veins, but thus far few of these have been extensively developed.

The first prospecting on the quartz veins was done in Custer county in 1875. The first ton of gold-bearing quartz subjected to careful treatment was taken in August, 1875, by Joseph Reynolds from a ledge near French creek about three and one-half miles above Custer and sent by wagon and team at a cost of forty-five dollars to Cheyenne, Wyoming, where it was sampled and sent to Georgetown, Colorado. Some of the ore was found to run as high as seventeen dollars a ton.*

The first claim to be worked extensively was the Grand Junction, located seven and one-half miles northwest of Custer near the Custer-Pennington county line. The claim was staked in April, 1879, and in 1880 a twenty-stamp mill was erected. This mill ran intermittently until 1882, during which year twenty more stamps were put in. The enlarged mill ran until 1885, when the ore, which had been chiefly free-milling near the surface, became too refractory for amalgamation, and work was suspended.

Among other properties early located are the Atlantic, the Old Bill, the Old Charlie, the North Star and the May Flower near Custer; the King Solomon and the Grizzly Bear near Hill City; and the Montana near Rochford. Mills have been erected on some of these properties, all of the mines have been intermittently productive, and most of them have afforded some rich ores.

Many properties have recently become of importance, and several of the older abandoned mines are again receiving attention. Of the present active mines the Holy Terror, of Pennington county (plate 2), and the Uncle

* Tallent, Annie D. *The Black Hills; or, the Last Hunting Ground of the Dakotas*, St. Louis, 1899, p. 165.

Sam, of Lawrence county (plate 3), are the chief producers.

Quartz veins are abundant throughout the area occupied by the Algonkian metamorphic rocks. They generally, but not always, follow the foliation of the slates, schists and quartzites, with which they occur, and the individual vein may occasionally be traced a considerable distance. As frequently observed elsewhere, they show great variation in thickness, especially in the schistose areas, where the veins are often of lenticular form, and where in the more extensive veins swelling and narrowing seem to be the rule rather than the exception. The thickness seldom reaches fifty feet, and in most cases it is very much less than this, much of the mining and exploratory work having been carried on along veins less than four feet in thickness. The veins seem to be more numerous in the schists than in the slates, but the veins in the slates are in general said to be thicker, more clearly defined and more persistent than those found in the schists.

Prof. Newton refers to the veins as "veins of intercalation" and states that some of them appear to be "true veins" formed by the collection of quartz along lines of separation of the strata. Prof. Jenney in much the same way states that they are not "true fissure veins," but designates them as "interlaminated fissure veins," and adds that the veins are chemical precipitations from waters holding silica in solution, partly, at least, derived from the wall rocks of the veins, and undoubtedly formed during the folding of the strata, at which time the gold must also have been deposited. In this connection it should be borne in mind that the foliation which has been interpreted by some investigators of Black Hills geology as largely or wholly co-incident with original stratification planes, has been shown by Prof. Van Hise to be due chiefly to metamorphic processes, which have practically obliterated the stratification planes except in favored localities, where, with careful study, the original relations may be discerned.

The veins have a general north-south trend, sometimes swaying considerably to the east or west. Such veins are locally known as "formational veins." Occasionally cross

veins are found which follow fractures at a considerable angle to the foliation, not infrequently being approximately at right angles to the general trend of the formational veins. These cross veins, like the north-south veins, may be gold-bearing and in some cases are said to be quite rich.

The quartz of which the veins are composed is highly crystalline and is generally opaque white. When auriferous it is more often bright and translucent, with not infrequently a bluish or black tinge. Iron oxide in the form of limonite commonly occurs intimately associated with the quartz near the surface and occasionally in considerable quantity. Pyrite is an associate, but is found only in the deeper workings. On the Chilkoot and neighboring properties, eight miles east of Custer, crystallized graphite is found filling minute cavities in the quartz. Tetradymite is found as an associate on the Newark property near Custer.* Siderite is common in many places, particularly in the vicinity of Rochford. Galena is common in the Uncle Sam mine at Perry (plate 3), particularly in connection with the richer pockets of gold, and sphalerite is not an infrequent associate. Other mineral associations doubtless occur, but apparently little attention has been given to their observation.

The gold in all of the developed properties is more or less free-milling, as may be readily seen by the ordinary pan test. It is almost completely free near the surface, but becomes gradually more and more refractory with depth. For some reason not yet clearly explained, the concentrates have not yielded readily to metallurgical processes and largely for this reason many of the apparently valuable properties are now idle. The Holy Terror mine at Keystone (plate 2) which is down 1200 feet vertical has perhaps had the longest approximately continuous run of all the mines on vein quartz. In this mine the free gold has continued in abundance with depth, but even here, and especially in that portion of it formerly known as the Keystone mine, the concentrates are important. The refractory ores from various mines are now being experimented upon,

* Smith, F. C. Notes on Black Hills Geology, Black Hills Mining Review, Sept. 3, 1900.

and doubtless a satisfactory method of treatment will be found.

One feature of interest in development work within the granite area, is that the granite is younger than the auriferous veins, and since it often protrudes into the metamorphic rocks in the form of dikes, sheets and irregular masses must necessarily cut such auriferous quartz veins as may have originally intersected its pathway. In many such cases the displacement is not great, and by going through the granite flow the vein may be again encountered without great expense. This has been done in a number of instances, particularly in the Chilkoot district.

The gold occurs generally in minute particles scattered through the quartz, but many properties have afforded excellent display specimens. The value of the workable veins varies widely. Twenty-dollar ore is common, fifty-dollar ore is not infrequent, and much higher assays are occasionally observed. The Holy Terror mine, until recent litigation hindered its development, showed phenomenally rich ore for many weeks in succession, and the statement is made that by means of a ten-stamp mill it has produced as high as \$70,000 in one week. The vein is narrow, and sinking has consequently progressed rapidly, the vertical shaft being now down 1200 feet.

The rather checkered career of many of the mines on quartz veins has greatly handicapped the study of these deposits. Unwise management and difficult conditions have too often combined to render efforts unsuccessful, which apparently should have gained excellent returns. Recently there has been improvement in many ways. Perhaps never before has there been so much development work done on quartz veins during the same length of time as during the last twelve months. Gold exists in these veins in quantity, and, although presenting difficulties often not easily overcome, they will doubtless rise in the future to a much more commanding place than they now hold.

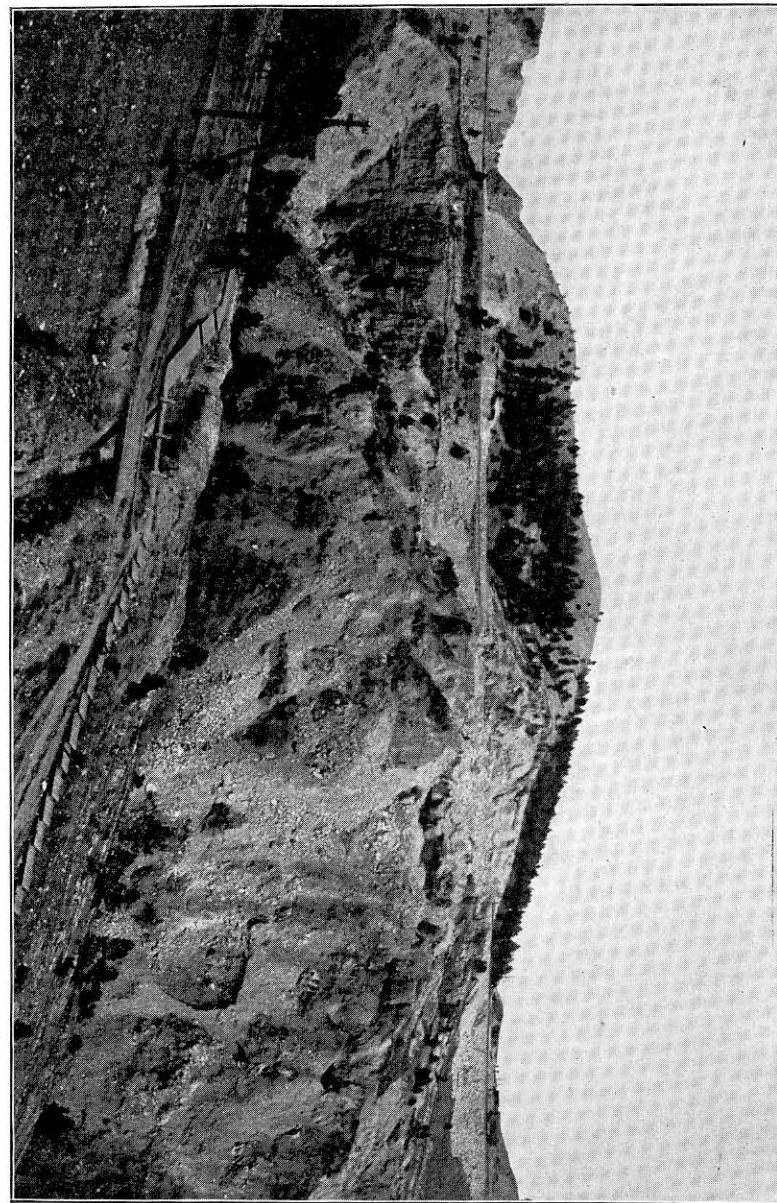
AURIFEROUS PYRITE VEINS.—No veins of pyrite in the Hills are worked exclusively for their gold content. Pyrite veins in various parts of the Hills have received at-

tention in past years, but at present, so far as I can learn, only three properties are producing ore. These are the Slavonia mine near Lead and the Gilmore and the Seim mines near Deadwood. The Bion, near Galena, contains a wide vein, but is not producing. Other properties could doubtless furnish much material were railroads convenient and smelter demands sufficient. All of the ore now produced is sold to the Golden Reward smelter at Deadwood for use as a flux in the reduction of the Cambrian siliceous ores, the value of the pyrite depending somewhat upon its purity and the amount of gold and copper present. The pyrite from the mines mentioned carries from fifty cents to three dollars a ton in gold and generally a small per cent of copper, the latter occasionally running up to three or four per cent or more. Silica is generally present in greater or less amount, and the per cent of graphite is occasionally high.

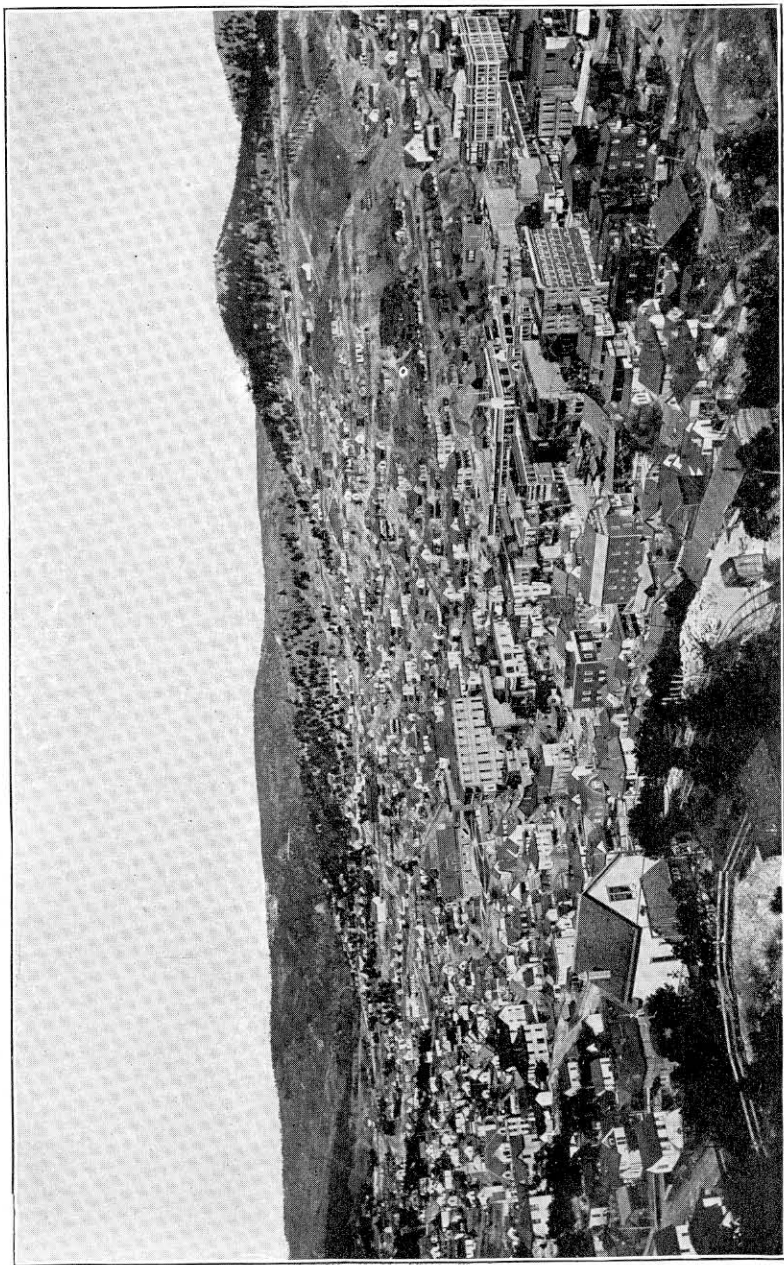
The Seim mine has been worked since 1890, and the Slavonia for a considerable time. The Gilmore mine has just begun producing. No account of the total output is at hand, but the present production of the mines is from 50 to 100 tons a day.

AURIFEROUS DIKES, SLATE BRECCIAS AND FISSURE VEINS.—The porphyritic rocks of the northern Hills, as well as the dioritic and granitic rocks of the central and southern Hills, are occasionally auriferous, but, with some few exceptions, little economic importance has been attached to them. In Pennington and Custer counties the dioritic schists have been exploited with some confidence, but as yet none of the properties have become strong producers. The porphyries near Galena are of considerable geological importance, and occur in the form of dikes and sheets. Gold is widely diffused through these rocks, it being found both in the dikes and in the sheets, generally with iron pyrites, but sometimes free.

Interesting slate breccias and fissure veins also occur in the Galena district. Having had no opportunity to examine these, I quote from Prof. Jenney, who has studied them and who describes them as follows:



PART OF ONE OF THE HOMESTAKE OPEN CUTS, LEAD.
Porphyry above the railroad; mostly slates and schists below. V shaped portion on the left contains porphyry and quartzite and is enlarged in Plate 9.



LEAD CITY.

The Homestake mine and mills join this view on the right.

Broad zones or belts of gold-bearing breccias traverse the schists and slates in the Union Hill, Hoodoo and adjacent mines. These breccias are made up of angular fragments of slate, a confused mass of material without any apparent order of arrangement; the pieces of slate of all sizes and shapes cemented together into a solid rock. Among the rock fragments may be found siliceous slates, mica slates and schists commonly occurring in the vicinity, with less frequently quartz derived from the older veins. The slate fragments are more or less decomposed, softened and bleached in color, probably owing to the action of heated alkaline waters during the mineralization. The porphyry intrusions in the breccias are locally kaolinized; quartz alone has resisted alteration. In some localities the breccias are formed of dike-like masses of porphyry, through which the fragments of slate are irregularly distributed, evidently having been inclosed in the fluid igneous rock at the time of the intrusion. In other places porphyry is absent, and the breccias are entirely composed of material resulting from the crushing and alteration of the primary rocks. These distinctions are not well defined; every gradation in the character of these fragmental rocks is seen in the district. Dikes and intruded masses of porphyry with only scattered intrusions of slate gradually merge from an increase in the relative proportion of inclosed fragments into breccias largely made up of slate. Iron pyrite containing gold is disseminated throughout the breccias in varying amount. The pyrite is mainly deposited in the cementing material, though the slate fragments have a little disseminated mineral. The gold, together with the pyrite, is readily separated from the ore by concentration; a small part of the gold is free in certain ore deposits and can be amalgamated. Near the surface the ores are oxidized and a somewhat larger proportion of the gold is free. These ore deposits are of great extent; a breccia developed in the Hoodoo mine is more than 200 feet in width and of unknown length on its course. Similar ore-bodies occur in the adjoining mines and can be traced on the surface for distances of 1000 to 2000 feet. The origin of these breccia deposits appears to have been due to crushing of beds of slate by movements of the strata, caused by the intrusion of the igneous rocks, the mineralization taking place at a subsequent period.

Fissure veins traverse the slates, locally extending up into the porphyry overflow. The veins are commonly narrow and frequently carry high grade ore. A vein of this type lately opened in the Hoodoo mine is six feet in width, the ore slate and quartz carrying pyrite and free gold. Narrow veins filled with decomposed porphyry, bearing gold and often high grade, occur in the porphyry overflow covering the surface of Union Hill; certain vertical fissures carry ores of copper.*

* Report on the Geology and Ore Formation of the Black Hills. Black Hills Mining Review, March 21, 1898, pp. 11 and 12.

IMPREGNATED ZONES.—The ores of the impregnated zones are of great importance. One of these zones, known as the Homestake Belt, has furnished approximately three-fourths of the total gold output of the Black Hills, and notwithstanding the recent rapid advancement in the utilization of other varieties of ore, this belt is now affording more than one-half the annual output.

Thus far the ores of the impregnated zones have been continuously worked for a considerable length of time only in Lawrence county. Many claims, however, in Custer and Pennington counties are said to carry as high values as the Homestake ore, and some of the ore bodies in these counties are large.

Of the properties outside the Homestake Belt that have been worked, perhaps none have been more extensively exploited than the Standby at Rochford. This mine was opened in the early years of Black Hills history, and, although worked intermittently, has been a producer of no mean consequence. In the past only the free-milling gold was saved, no effort being made to secure the refractory values. At present substantial exploratory work is being done on lower levels than before, and efforts will be made to save such concentrates as may be found. The Bullion and other mines near Keystone have furnished considerable gold, but these are not now producing. In the Hornblende district west of Rochford several mines are being developed, but none have reached the stage of steady production. Custer county also has various properties of a similar nature, but none are active producers. In several of the properties coming under the class of impregnated zones, the gold is practically all free-milling at the surface, while in others it is only partly free-milling or mostly refractory. Several years ago Professor Carpenter, while Dean of the School of Mines, tested some of the more refractory ores and made calculations as to their probable value if mined and treated carefully on a large scale, such as is done by the Homestake company. It is sufficient here to state that in several instances favorable results were reached.*

* The Mineral Resources of the Black Hills. Preliminary Report of the Dakota School of Mines, 1888, pp. 118-121.

The Homestake mine, widely known as the greatest low grade gold mine in the world, is the typical example of the class, and having been an important factor in the development of the Black Hills, may be described in some detail.

The mine lies to the southwest of Deadwood, being situated between Whitewood creek and Deadwood gulch. Near the mine and at equal pace with its development, a busy town, Lead (pronounced *Leed*), has grown up, the town, now the largest in the Black Hills (plate 5), taking its name from the miners' term "lead," meaning lode.

The first claims located on property now controlled by the company were the Giant and the Old Abe. These were located by J. B. Pearson, December 11, 1875, and aside from placer claims, are believed to have been the earliest mineral locations in the Hills. Early in 1876 the Homestake, the Highland and the Golden Star were located, and the Old Abe, which had been previously abandoned, was relocated. During this year the owners of the Homestake claim prosecuted vigorous development work and constructed and operated a crude arrastre, with which they obtained excellent results.

In 1877 two stamp mills were utilized in treating the "belt" ores. The first, a ten-stamp mill, later increased to twenty stamps, was erected by the Racine Mining and Milling Company, the mill arriving at Lead April 7th. The stamps began dropping April 15th, and the first clean up was made April 20th. The second mill, erected by Mr. Enos, who had purchased a considerable portion of the Homestake claim, was put in operation in July. Subsequently, when the Homestake company acquired the properties from which these mills had obtained their ore supply, the mills were torn down and the machinery removed to other localities.

The Homestake Mining Company was incorporated November 5, 1877, but its real history began several months prior to that time. In the fall of 1876 Mr. L. D. Kellogg, a representative of Mr. J. B. Haggin, and Senator Hearst, of California, arrived in the Hills and made a preliminary examination of various properties in the vicinity of Lead.

In January, 1877, Mr. Samuel McMasters visited the locality under the direction of the same individuals, and during the summer and fall a thorough examination was made. Senator Hearst then personally inspected the properties, purchased various claims, and arranged immediately for the erection of an eighty-stamp mill. The mill was shipped by rail to Sydney, Nebraska, from which point it was freighted to the mine by ox team, the cost of transportation from Sydney to Lead amounting, it is said, to \$33,000.

In July, 1878, during which month the eighty stamps were placed in commission, the first and only assessment in the history of the company was levied. This was at the rate of a dollar a share and afforded \$200,000 required for the erection of the mill.

As the magnitude of the ore deposit became more clearly defined by exploratory work, the milling capacity was increased, important timber and water rights were acquired, a short but important railway line was constructed, and absorption of various companies controlling adjoining properties was brought about. Some idea of the company's present surface equipment can be gained by reference to plate 15, in which there is shown a view of the hoists, mills, etc., near Lead. This does not include the 1300-ton cyanide plant recently constructed below Lead, the 700-ton cyanide plant now building at Central, nor the hoists and stamp mills at Terraville and Central.

In general the mine has shown a steady growth in production, and most of the mills have been running continuously. Within two years after the installation of the original Homestake eighty-stamp mill a total of five hundred eighty stamps were dropping. These were distributed as follows: The Homestake at Lead, erected 1878, eighty stamps; the Father DeSmet at Central, erected 1878, eighty stamps; the Golden Star at Lead, erected 1879, one hundred twenty stamps; the Deadwood at Terraville, erected 1879, sixty stamps; the Caledonia at Terraville, erected 1879, sixty stamps; the Golden-Terra at Terraville, erected 1880, sixty stamps; and the Highland at Lead, erected 1880, one hundred twenty stamps.

All of these mills continued in active operation until 1892, at which time the Father DeSmet ceased, and in 1893 the Caledonia followed. This action was necessitated by the scarcity of water and by the low tenor of the free-milling ore in these mines. About this time, however, the Homestake mill increased its capacity by the addition of twenty stamps, the Golden Star by the addition of forty stamps, and the Highland by the addition of twenty stamps.

In 1899 a largely increased supply of water was obtained from Spearfish creek, and in 1900 a 1300-ton cyanide plant for the treatment of concentrates was completed. At present all of the mills are in active operation, total number of stamps dropping being 900, distributed as follows: The Homestake, 200; the Golden Star, 200; the Highland, 140; the Deadwood-Terra, 160; the Caledonia, 100; the Father DeSmet, 100.

The ore-bearing area of the Homestake Belt as definitely exploited covers an area approximately one and one-half miles long and one-half mile wide. Two active companies are now carrying on extensive exploratory work outside of this area, the Hidden Fortune Company to the north of Lead, and the Black Hills Development Company to the south, in the belief that the ore bodies may be found beyond the boundaries as generally defined.

The ore lies in lenticular bodies of great extent, the workable portions in some places exceeding 400 feet. In one place it is said to reach 525 feet. By reason of this great width much of the ore has been worked by open cuts, some of which cuts have grown to great size, as shown in plates 4 and 15. At present most of the mining is underground. The deepest working levels are 1100 feet below the surface. The ore bodies have practically the same foliation as the surrounding country rock, the general strike, according to Dr. Carpenter, being N 37 $\frac{3}{4}$ ° W and the dip steeply to the east. Amphibolites and porphyries are present. The amphibolites conform closely to the foliation of the enclosing metamorphic rocks, while the porphyries, sometimes in dikes and sometimes in sheets, either stand approximately parallel to the foliation or lie across the uneven edges of the upturned rocks.

The gold occurs chiefly in chloritic and amphibole schists highly impregnated with quartz. The principal associate minerals are iron pyrite, pyrrhotite and arsenopyrite. Ore highly charged with iron pyrite generally falls below the average value in gold, while the arsenopyrite ore is more often above the average. In the surface workings iron oxide is abundant, and the color of much of the ore is reddish brown. On the lower levels, where the unchanged sulphides abound and where the quartz is clear and the schists are fresh, the general color is green.

The free-milling character of the ore is pronounced. Practically all of the values in the surface ores are extracted by simple amalgamation. During the first twelve years of mining operations no attempt was made to save concentrates, although the deeper ores gradually became less free-milling. Concentrates have been saved since 1890. Until two years ago they were sent to the smelter at Deadwood for treatment, but in 1900 the company erected a 1300-ton cyanide plant at Lead, which is now successfully treating the tailings by the cyanide process. The company, having proved to its satisfaction that the cyanide process can be used advantageously, has recently begun the erection of a second plant of 700 tons capacity, the location of this plant being at Central.

The sulphides vary generally from three to five per cent of the ore, but occasionally run up to ten per cent or higher. The assay value of the concentrates, of which about 85 per cent is iron sulphide, averages \$7 a ton. The present average value of the gold in the ore is usually given at about \$4.50 a ton, of which approximately about \$3.50 is saved. The new cyanide plant will materially lessen the waste.

Concerning the origin of the ores, Dr. Carpenter suggests that at the time of deposition of the enclosing rocks, large quantities of proto-sulphide of iron were formed through the agency of decaying organic matter whose presence at that time is attested by the large quantities of graphite now found in these beds. Originally this proto-sulphide was practically free of gold, but later by the action of ferric salts in solution the proto-sulphide was changed

to bi-sulphide, and the iron solutions which wrought the change also brought the gold which is now found in these deposits. The intrusion of the porphyry, he thinks, has been beneficial for two reasons: First, it has rendered the ores more free-milling. Second, it has in its neighborhood produced either an enrichment of the deposit or a further concentration of what gold originally existed in it.*

In view of the fact that the Hills were the seat of much igneous activity previous to the metamorphism of the Algonkian series, as indicated by the widespread distribution of basic rocks now represented by the amphibolites, and further that the auriferous quartz veins were formed prior to the granite intrusion, which took place during Algonkian time, it seems possible that the amphibolites may have caused or controlled the original deposition of much of the gold now found in the impregnated zones.

In the absence of careful investigation it is difficult to say whether or not the amphibolites did exert any controlling influence, but their present relation to the metamorphic sedimentaries suggests that they may have been forced into the Algonkian sedimentary rocks in much the same way that the post-Cretaceous eruptives have been injected among the Cambrian and Carboniferous rocks. This being the case, subsequent mineralization may have taken place in some way not greatly different from that which has been brought about in the northern Hills since Cretaceous time, the chief difference being that in the former the final processes left the gold in veins and in impregnated zones in a partially or wholly free-milling condition, while in the latter it is in the form of ore shoots and is quite refractory.

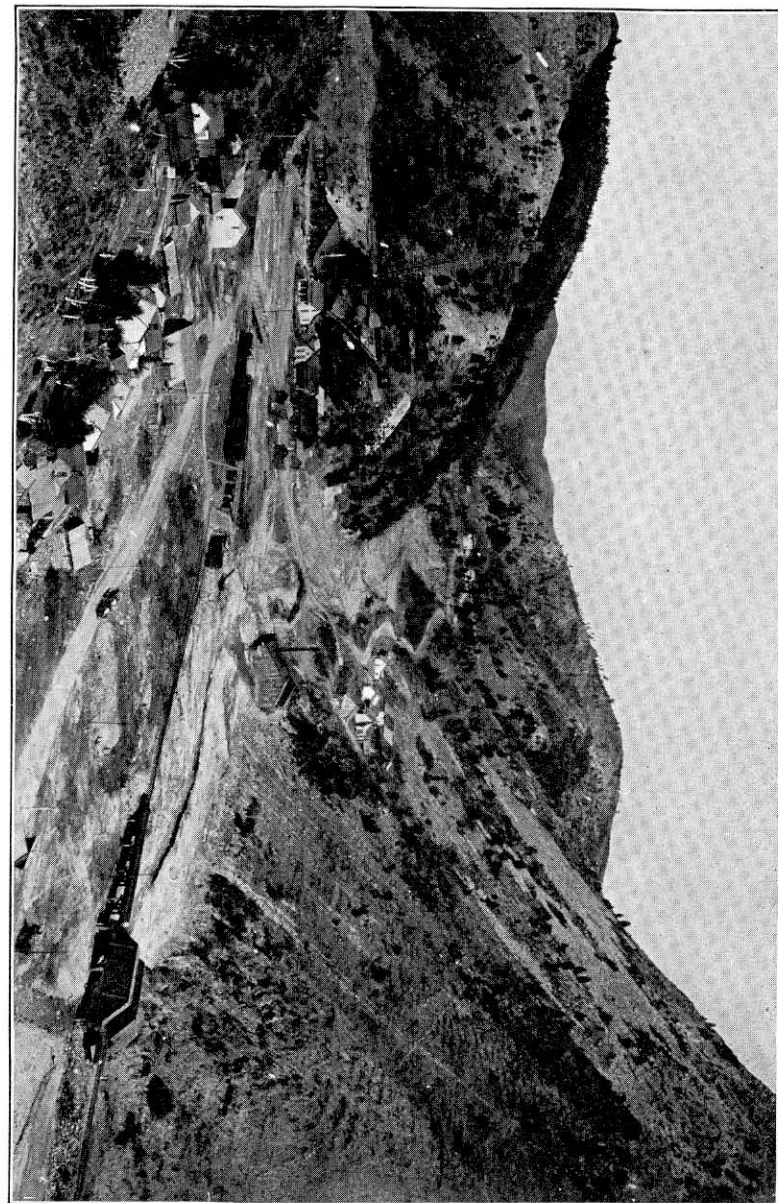
CEMENT ORES.—The auriferous character of the Cambrian conglomerate within the porphyry-capped hills to the west and southwest of Deadwood was discovered in the early part of 1876, only a little later than the finding of the rich placers in Deadwood gulch. Owing to the occasional high values which the ores contained and the ease with which the gold could be extracted, it being chiefly

* Preliminary Report of the Dakota School of Mines, Rapid City, 1888, pp. 113-115.

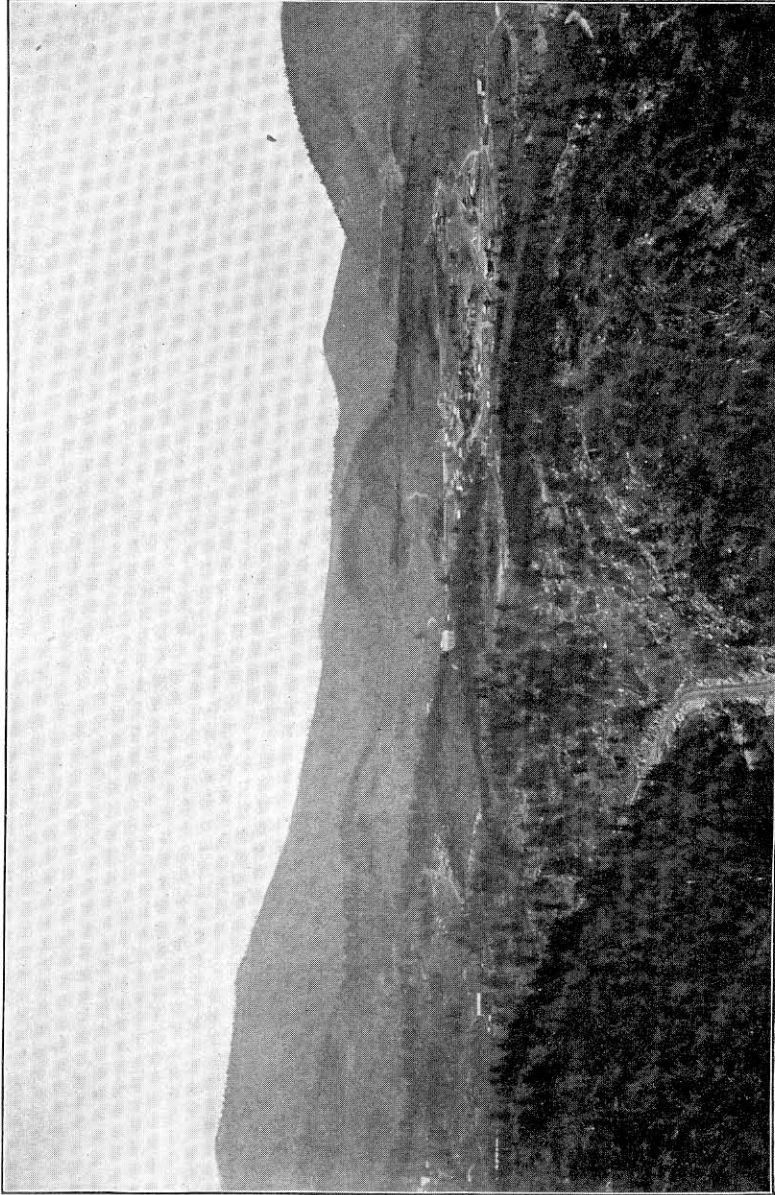
free-milling in the richer portions, the discovery led to immediate and pronounced excitement. For several months only the crude arrastre could be utilized in milling the ores, the first one having been constructed by Gardner, Chase and Company, owners of the Chief of the Hills, but these were efficient enough to indicate the profit with which the ore could be worked, and better mills were rapidly brought in to replace the hastily constructed makeshifts.

The first quartz mill brought into the Hills reached Deadwood September 25, 1876, and was placed a short distance above Gayville on Deadwood gulch. This pioneer quartz mill of the Black Hills consisted of a Blake crusher and a Bolthoff ball pulverizer arranged for steam power, and was brought to the Hills by Captain C. V. Gardner. The mill treated the rich conglomerate ore from the Hidden Treasure mine on Spring gulch, the claim having been located May 13, 1876, and before the close of the year it had produced twenty thousand dollars in gold. A little later Milton E. Pinney brought in the first stamp mill. This was a ten-stamp plant and was erected on the Alpha-Omega property near Central. This mill, as in the case of the Gardner mill, was purchased at Central, Colorado, and shipped by rail to Cheyenne, Wyoming, from which latter point it reached its destination by means of heavy freight wagons. The expense of hauling from Cheyenne was twelve and one-half cents a pound. The mill began dropping its ten stamps December 30, 1876, and quickly proved a profitable investment.

Mills rapidly multiplied until the early part of the year 1878, at which time the milling of conglomerate ores was at its height. About twenty mills were in active operation, dropping approximately five hundred stamps. After 1878 the richer deposits gradually became exhausted, and by 1881 work upon them had practically ceased. However, as in the case of the placer deposits, a few properties have continued to be worked in a small and intermittent way even to the present time. Recent developments in metallurgical methods seem to indicate the possibility of these ores being utilized to considerable profit in the future,



BLACKTAIL GULCH, GAYVILLE IN THE FOREGROUND.



RUBY BASIN. LOOKING WEST FROM SUGAR LOAF HILL.

Terry Peak on the left, Bald Mountain on the right.

owing to the fact that much of the ore contains refractory gold along with the free gold. Several companies are now studying the problems involved.

The conglomerate is at the base of the Cambrian rocks, known as the Deadwood formation as developed in the Black Hills, (the series here representing apparently only the middle Cambrian, hence not properly called Potsdam, as was formerly supposed), and lies unconformably upon the highly metamorphosed and upturned Algonkian rocks. The conglomerate is made up of well-rounded and sub-angular boulders of quartz, slate, schists, etc., derived from the Algonkian rocks on which it rests. In the Deadwood locality pebbles of hematite are frequent. The ore is tightly cemented by iron oxide and silica, with some lime, and generally requires blasting in mining and the stamp mill for crushing. It is this character which gave it the name "cement ore," by which it is generally known within the Hills. Two classes of ore are recognized, namely the oxidized and the unoxidized. The oxidized ore is deep brownish red due to the iron oxide present, while the unoxidized is more of a grayish color, fresh looking and contains considerable iron pyrite.

The conglomerate varies in character, being usually a single thick bed, sometimes in two or three separate beds, and occasionally is wholly wanting. In general it merges gradually above into coarse-grained sandstone or, where locally changed, into quartzite. It is found throughout a large part of the Hills where the proper horizon is disclosed, but in no place distant from the Deadwood locality has the gold been observed in remunerative quantities. The only other locality where there has been a worthy effort to work the deposits is at Gold Hill near Rockerville, at which place a ten-stamp mill was in operation several months during the year 1878, but the results were unsatisfactory and the work was abandoned. The formation dips gently toward the outer rim of the Hills and the ore is readily reached by lateral drifting. The areas which have produced the gold lie mostly to the east of the Homestake Belt, within a distance of one mile from the Belt, the ridge

between Deadwood gulch and Bobtail gulch being especially productive.

Mr. Walter B. Devereux, from whose paper* the writer has obtained much of the information concerning these ores, states that the productive material includes only a few feet of the lowest part of the conglomerate, and, like ordinary placer deposits, shows pay and lean streaks and the occurrence of most of the gold near bed rock. The gold, moreover, has the characteristics of placer gold, and in every respect the similarity between these deposits and recent placers is so prominent that Devereux gave them the name "fossil placers," a name by which they have since been frequently called. The Homestake Belt, now intersected and partially covered by post-Cretaceous eruptives, was evidently the immediate source of much of the gold, the Belt having served as the shore-line in this locality, while the heterogeneous materials of the conglomerate were being deposited in the shallow waters of the primordial sea. The relative positions of the Homestake Belt, the Cambrian strata containing the cement deposits, the capping porphyry and the recent placers along the present stream valleys are all shown in figure 1.

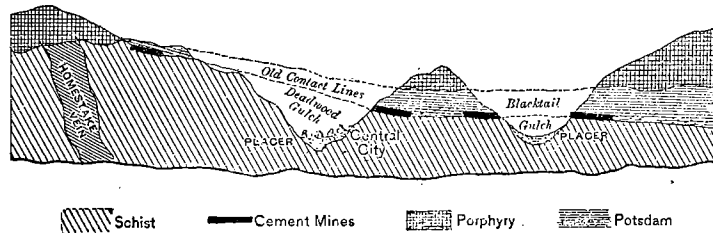


Fig. 1. Section showing relations of "Cement" Mines.

Devereux discusses at some length the immediate source of the gold, referring chiefly to the free-milling gold, and the methods of its concentration, giving facts to show that a small portion of it has been deposited through chemical solution, but that the great locating cause has been the

* The Occurrence of Gold in the Potsdam Formation, Black Hills, Dakota. Am. Inst. Min. Eng., Trans., Vol. X, pp. 465-475.

high specific gravity of the gold, in short, that the general conditions have been those of ordinary placer deposition. This idea has long prevailed, but it is possible that the post-Cretaceous eruptives may have influenced the concentration more than Devereux was led to believe.

In view of the fact that the Homestake Belt has been considered as the chief source of the gold, at least of the free-milling gold, it is interesting to note that certain comparative analyses of the metal lead to the same conclusion. Silver being more soluble than gold, it would seem that the cement gold should be purer than that from the Homestake Belt, the silver percentage being lowered during the process of disintegration and concentration, and further, that the finer the particles of cement gold the greater degree of purity it should have. The following analyses show this condition:*

	I. Coarse Gold.	II. Coarse Gold.	III. Fine Gold.	IV. Fine Gold.	
Gold	.902	.893	.917	.915	
Silver	.098	.107	.083	.085	
	Homestake.	Highland.	Terra.	Deadwood.	DeSmet.
Gold	.820	.830	.825	.850	.820
Silver	.170	.155	.160	.140	.170

Concerning the history of the successive geological changes which have taken place in connection with these ores, Mr. Devereux says:

First, we have the proof that the gold veins and the contained gold were in existence prior to the Potsdam [Cambrian] period. Then we have the Potsdam seas washing away the debris resulting from the disintegration of the quartz veins, and depositing it in deeper water, in accordance with its various specific gravities. At the same time the gradual wave action carried the gold to the bed rock in the same manner as it is settled in a miner's pan. The Homestake vein, by reason of its greater durability, formed a reef or low island, which never became deeply submerged. After a time these sediments became insular, and as such remained undisturbed, gradually becoming cemented into rock, until the recent eruptions of porphyry took place, causing intense local metamorphic action.

* Devereux, Walter B. The Occurrence of Gold in the Potsdam Formation, Black Hills, Dakota, Am. Inst. Min. Eng., Trans., Vol. X,

The gold, which up to this time had suffered perhaps a loss in silver only, now became itself partially dissolved, where the solvents were sufficiently powerful, and was again at least partially precipitated as thin films in the schists below.

Once more a period of rest occupied the time, until the erosive action of fresh-water streams cut through the upper strata and began to disintegrate the matrix of the gold and afforded material for a new concentrating process. Disintegration and concentration have been going on until now, when the hand of man has hastened the work of nature.

This gold from the conglomerate, which found its way down the slopes to the gradually lowering bottom of Deadwood gulch, was joined with new supplies brought from the Homestake vein through lateral gulches, and the result was the great Deadwood placer. That in Blacktail, however, received no new accession and remained a placer which had received its gold entirely from the Potsdam sediment.*

The gold particles found in the cement are not large, seldom reaching a value of more than two or three dollars. Larger pieces are not uncommon in the Homestake quartz. The cement gold is made up chiefly of smooth, rounded, slightly flattened grains having generally a thin covering of iron oxide, which is easily removed in the process of milling.

The value of the ore varies widely. During the early days of mining, before the richer streaks were exhausted, ore is said to have run as high as fifty dollars a ton, with limited quantities near bed rock much higher. To-day values as high as twenty dollars are occasionally found, but the average in most of the mines is about four dollars; large bodies are, however, said to average five dollars or more. Such bodies are found in various places along Blacktail gulch and elsewhere, and some work is now being done upon them. Plate 6 gives a view up Blacktail gulch taken from the south side of Deadwood gulch at Gayville.

The free gold of the Cambrian is not confined to the conglomerate, but is disseminated throughout the formation. Irving states that unaltered Cambrian shales and sandstones two or three hundred feet above the basal quartzite on the west bank of Spearfish creek have yielded

* The Occurrence of Gold in the Potsdam Formation, Black Hills, Dakota, Am. Inst. Min. Eng., Trans., Vol. X.

from eighty cents to two dollars a ton. Free gold is said to be found also in unaltered glauconitic shales near Crown Hill, and the writer has heard many statements to the same effect concerning the sandstones and shales near Rockerville.

With few exceptions, this gold above the basal conglomerate is of no economic importance. One important locality near Lead, the Hidden Fortune mine, has furnished several car loads of excessively rich ore, but the ore was found only a short distance above the conglomerate horizon and may perhaps be rightly considered with the conglomerate ores. Plate 19 gives a view of this interesting locality. The gold was obtained from the open cut at the right of the building near the center of the view.

So far as known the refractory gold of the conglomerate, although averaging low in value, is in much the same condition as the siliceous ores so abundantly developed in and above the lower quartzite. For a fuller description of these the reader is referred to the discussion of siliceous ores in the following pages.

CAMBRIAN SILICEOUS ORES.—The siliceous ores, known also as refractory ores and formerly as Potsdam ores, are found only in the northern Hills. The producing areas lie within Lawrence county and are two in number, designated by Prof. F. C. Smith as the Northern Connected district, lying chiefly to the west and southwest of Deadwood and Lead, and the Galena district, in which the town of Galena is situated.* Of the two the Northern Connected district is much the larger in areal extent and is the greater producer. Its chief centers of interest are: Ruby basin (plate 7), Bald mountain, Portland, Crown Hill, North Lead, Sheeptail gulch, Squaw creek, Spearfish creek and Yellow creek. In the Northern Connected district the ores carry some silver with the gold, while in the Galena district gold, silver and lead occur.

Igneous rocks of post-Cretaceous age have cut and intercalated the Cambrian strata in the districts mentioned to a

* Smith, F. C. The Potsdam Gold Ores of the Black Hills of South Dakota. Am. Inst. Min. Eng., Trans., Vol. XXVII, 1897, pp. 404-423.

marked degree. Phonolite, quartz-porphry, etc., have come up through the Algonkian metamorphic rocks in the form of dikes (plate 8), and in many instances continuing as dikes have cut also through the Cambrian and Carboniferous rocks, or, failing to do this, have spread out as extensive sheets (plate 9) or irregular masses or as well developed laccolites. Among these forms of intrusions the laccolites are by far the most conspicuous and important. The best illustrations are Sugar Loaf hill and Ragged Top mountain, but Terry peak, War Eagle hill and Bald mountain east of Spearfish creek and Johnston peak between Bear gulch and Beaver creek (plate 10) have a similar origin. Sheets make up a smaller total amount of the eruptive material, but their number is important. The thickness of the sheets varies from a few inches to two hundred feet or more, and indeed they pass by gradually increasing thickness into laccolitic masses. Irving states that the sheets vary greatly in their regularity and persistence, sometimes being short, thick and irregular, and again long, thin and of great lateral extent; and that the more extended and persistent sheets lie between the heavy and less easily broken members of the Cambrian series, while those which assume a very irregular form are most commonly in the thicker horizons of very fine shales, where fracture is equally easy in all directions.* He estimates that these sheets in localities near the centers of eruption have increased the total thickness of the Cambrian formation nearly one-fourth. The dikes are found in considerable numbers and occasionally become of importance. The material of which these intrusive masses are made up are chiefly phonolite and quartz-porphry. When found together the phonolite is observed always to cut the porphyry, indicating different periods of eruption, the phonolite being the later.

The ore is found at various horizons within the Cambrian, chief of which is immediately above the conglomeratic quartzite, which lies unconformably upon the Algon-

* A Contribution to the Geology of the Northern Black Hills. *Annals N. Y. Acad. Sci.*, Vol. XII, No. 9, p. 229.

kian schists and slates. This horizon is easily distinguished and is generally known among mining men as the "lower contact." Owing to the approximate uniformity of the higher shales and thin sandstones (plate 12), together with their many structural disturbances, it has been difficult in many places to accurately locate the horizons of such ore bodies as occur within them. In the past it has been customary to refer to such deposits in a general way as "upper contact" ores. The proximity of some of these ore bodies to a heavy bed of scolithus sandstone known as the "worm-eaten" sandstone, near the upper part of the Cambrian, has possibly given origin to the name. Careful observation has revealed the fact that valuable ore bodies may be found at several horizons between the basal quartzite and the scolithus sandstone; hence the distinctive meaning of the term "upper contact" has largely disappeared. The lower contact ores are in many places underlain by quartzite sufficiently auriferous to be classed as ore. This is particularly true of the North Lead, Yellow Creek and Ruby Basin areas, and may upon further examination be found common in other localities.

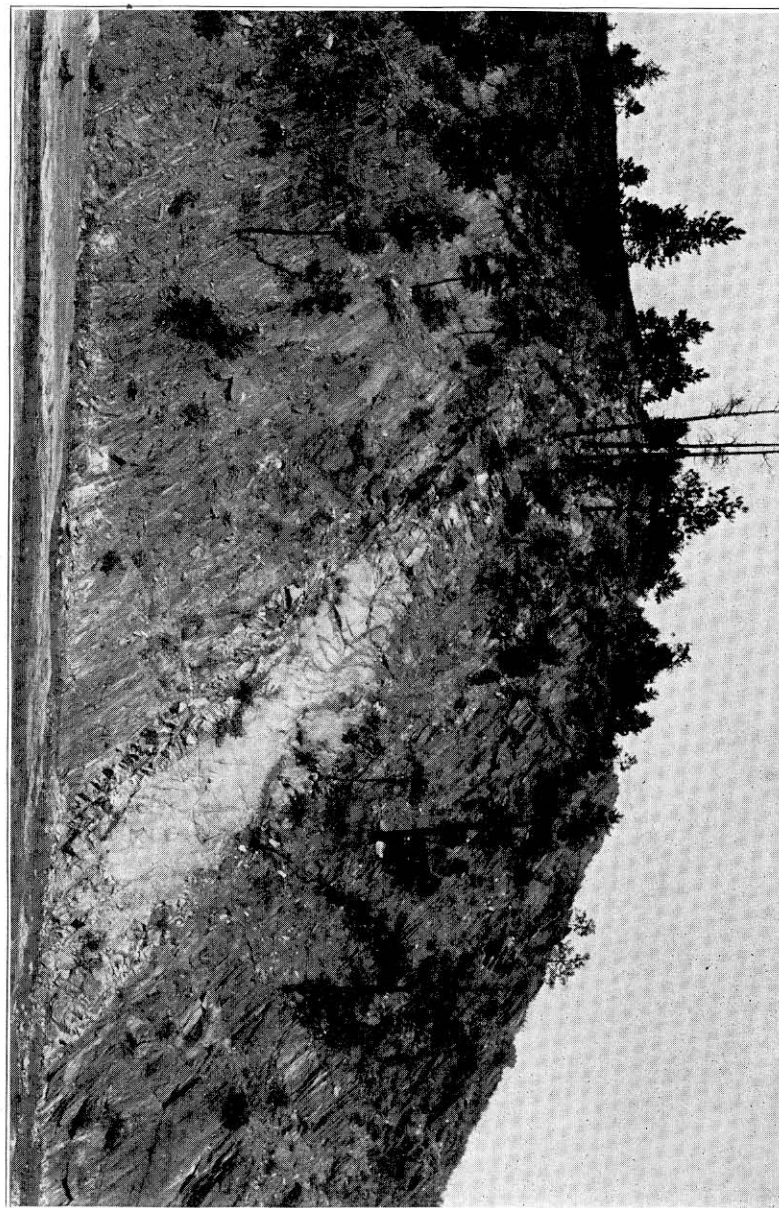
So far as known, all ore bodies worked in the Ruby Basin, Yellow Creek, Crown Hill, North Lead and Sheeptail Gulch localities are on or within the lower quartzite. (See plate 12). On Squaw creek and in the Galena district higher ores are also worked, and in some places the definite horizon can be readily learned. At the Cleopatra the ore bodies are immediately beneath the scolithus sandstone, and this is stratigraphically about three hundred feet above the lower quartzite. Whether or not the lower ores are present has not yet been determined, but it is believed that exploratory work will reveal them. In the Portland or Green Mountain area all of the mines with one exception, the Decorah, are from two to three hundred feet above the base of the Cambrian.* It must be borne in mind, as has been previously indicated, that igneous intercalations are frequent throughout much of the siliceous ore district; hence, in estimating the thickness of the sedimentary series,

* Irving, John D. A Contribution to the Geology of the Northern Black Hills, p. 301.

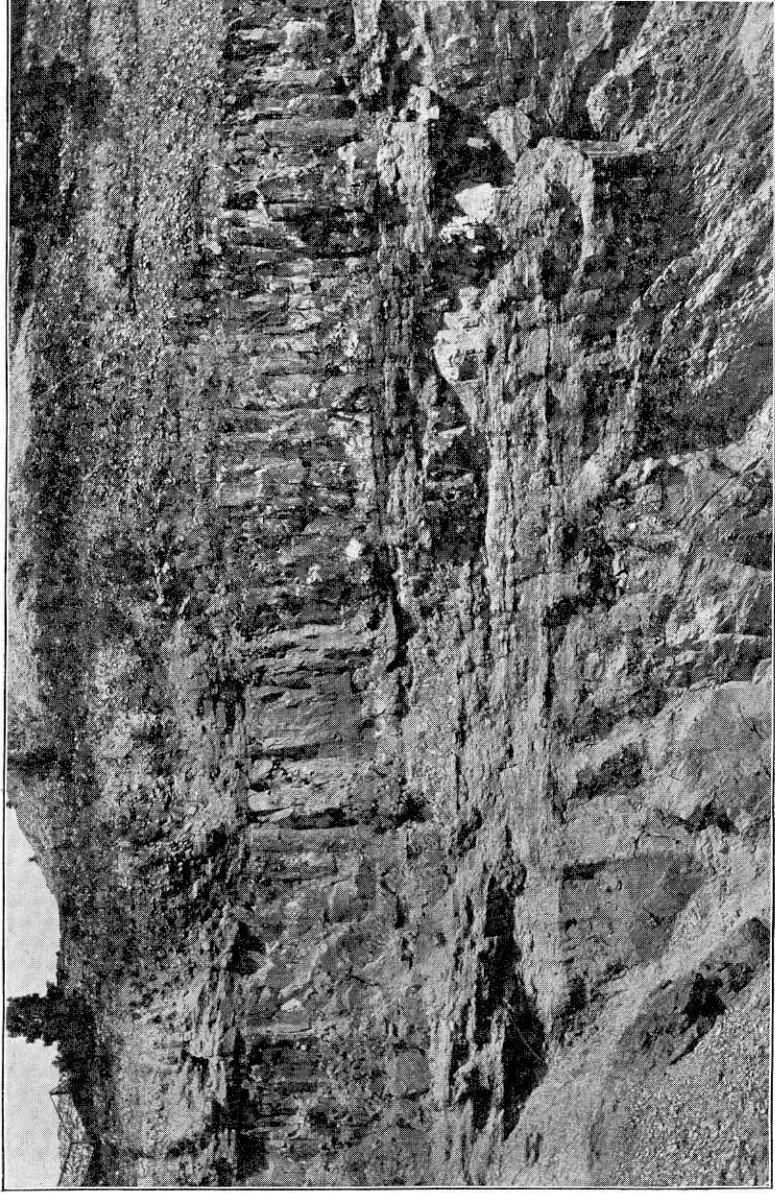
allowance must be made for the possible presence of the igneous rocks. This is illustrated in the following section observed in the Dacy shaft and drill hole at Ragged Top camp:

SHAFT—	
Limestone.....	505 feet.
DRILL HOLE—	
Limestone.....	70 "
Sandy lime-shale	80 "
Variogated shale.....	167 "
Black shale.....	5 "
Green sandy shale.....	5 "
Black shale.....	17 "
Phonolite.....	37 "
Black shale.....	18 "
Variogated shale.....	19 "
Black shale	3 "
Variogated shale.....	19 "
Sand rock.....	5 "
Quartzite	23 "
Trachyte, not passed thro'	40 "

It is also illustrated in the partial view of the open cut on the Homestake property (plate 9). The mines in Green mountain near Portland are almost immediately beneath a phonolite cap. The American Express mine in Sheeptail gulch has a roof of porphyry, and in the Sundance near Terry more than half of the ore is capped by similar material. The same is true in many places in the Big Bonanza on Fantail gulch and in the Decorah, and doubtless further investigation would show a like condition in many other mines. In the Union shaft in Whitewood gulch a considerable body of phonolite, which forms the base of the Sugar Loaf laccolite, was penetrated before reaching the sedimentary deposits, whose position in the shaft could be fairly accurately inferred from the outcroppings along the sides of the gulch in which the shaft is situated. In the Tornado shaft only shales and sandstones are encountered. Most of the shafts in Ruby basin have a depth of less than three hundred feet. The Delaware shaft, however, about one-half mile west of Aztec, in the southern part of the Ruby basin, reached nearly six hundred feet in depth before encountering the quartzite.

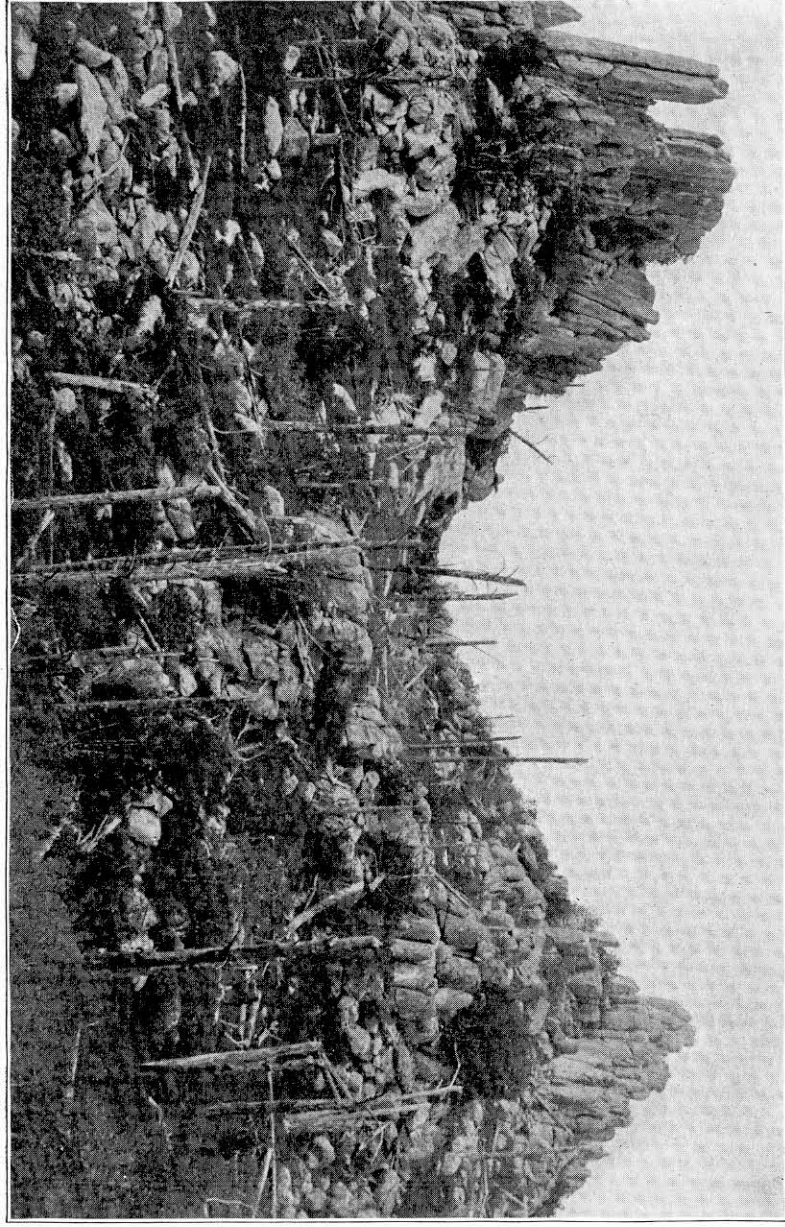


PORPHYRY DIKES IN ALGONKIAN SLATES NEAR PLUMA.



CAMBRIAN QUARTZITE WITH INTERCOLATED PORPHYRY RESTING ON ALGONKIAN SLATES AND SCHISTS,
HOMESTAKE OPEN CUT, LEAD.

PORPHYRY NEEDLES AT TOP OF JOHNSTON'S PEAK NEAR BEAR GULCH.



The structural relations of the Cambrian siliceous ores show some complexity, but it is usually of such a nature as to cause no serious hindrance to the proper development of mining property. Folding is occasionally observed, faulting frequently occurs, and the igneous intrusions sometimes aid in concealing true stratigraphic relations. Figure 3, which represents an east-west section through Terry, shows these features and readily indicates how it is possible to mistake one ore-bearing horizon for several.

Practically all of the siliceous ore bodies are in the form of shoots or channels in immediate connection with nearly vertical fractures running in a direction parallel to the longer diameters of the shoots. These fractures or "ver-

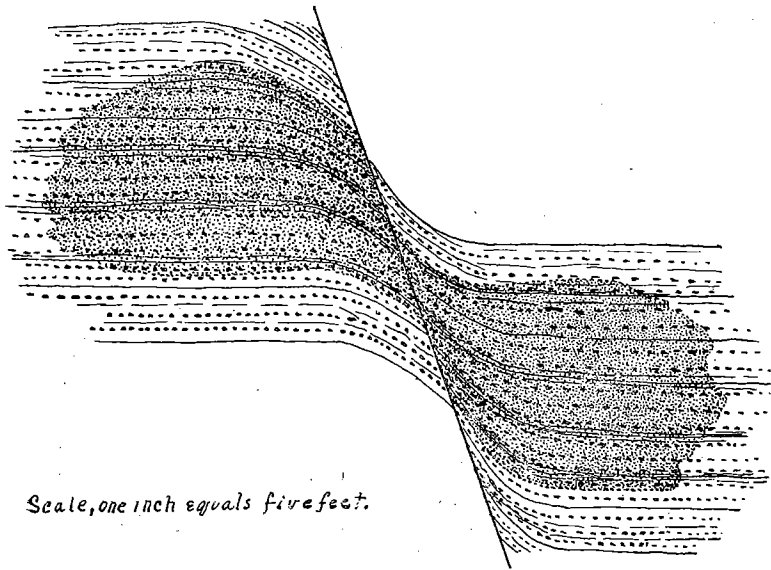


Fig. 2. Section through a faulted body of Siliceous Ore.

ticals" are usually slickensided and are frequently fault-planes along which more or less movement has occurred. This movement is well shown in the Cleopatra mine on Squaw creek, where eleven ore shoots have been encountered, and in each case there has been faulting varying from four to thirty feet. Figure 2 is a cross-section of one

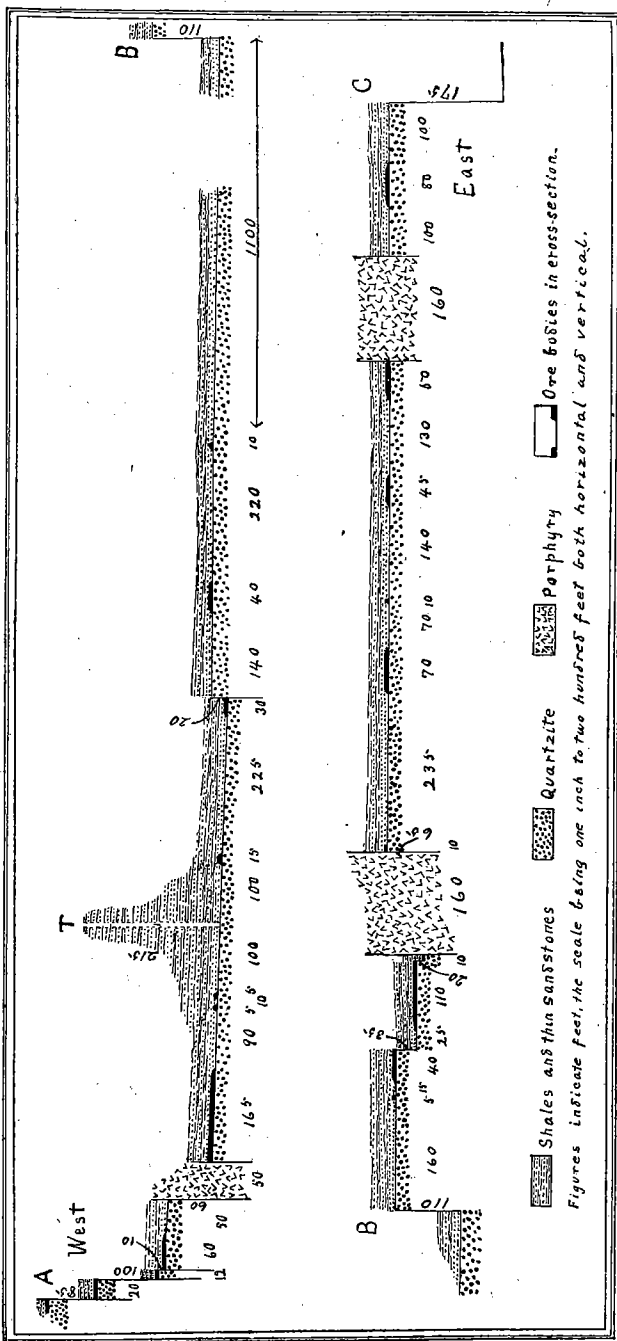


Fig. 3. East-West Section through Tornado Shaft, Terry.

of these faulted ore bodies which in its general relations is characteristic of all. The ore shoots vary considerably in shape, but in the main are greatly elongated bodies having a rounded or lenticular cross-section. They lie in a general north-south direction and are practically parallel with each other. Lateral branches or irregularities occasionally tend to conceal the parallelism, but this is not frequent. The north-south direction is perhaps best shown in Ruby basin, but in the southern part of this area they become deflected to the east. On Squaw creek the direction is nearly north-west-southeast. In the Portland area the direction is said to be approximately N 26° E. In the Galena district it is somewhat indefinite.

In all cases the ore shoots conform closely to the structure of the bedded deposits—locally known as the flat or blanket formation—with which it is found. The ore bodies, when not disturbed by movements subsequent to their formation, are seldom bounded by well-defined walls, so that the change from ore to country rock is imperceptible by ordinary means and must be determined by frequent assay. The ores must contain values sufficient to meet the demands of the metallurgical processes by which they are treated, and whenever the average fails to reach the required standard the lower grade peripheral ores are not removed. It thus happens that in many instances the real limits of the auriferous portions are not learned, and in such cases the dimensions of the bodies are greater than those given on the mine maps. They vary from the almost imperceptible horizontal band or vertical seam along the fracture to a body having a thickness of fifteen feet, a width of more than one hundred feet, and a length of one-half mile or more. In the Tornado mine owned by the Golden Reward company one ore body has been worked one and one-half miles and its terminals are not yet known. The widest place observed was one hundred seventy-five feet. Another body, also owned by the Golden Reward company, has been traced by workings a distance of five thousand feet, and in one place the pay ore reached a width of four hundred feet. Both of these are on the lower contact.

Of the higher ore bodies one in the Cleopatra mine on Squaw creek has been traced seven hundred feet, the greatest width being thirty feet. Doubtless a thorough examination of mine maps would show others fully as worthy to be noted. The distance between the ore bodies varies widely. The eleven ore bodies thus far discovered on the Cleopatra average sixty-five feet apart. In the Buxton mine the average is said to have been not more than fifty feet. Throughout much of the Ruby basin the distance is scarcely greater than the above. In the east-west cross-section through the Tornado shaft at Terry the width of the workable ore bodies aggregate 729 feet of the total 4,172 feet represented. This is nearly one-fifth of the section and is a remarkable showing in view of the fact that one barren stretch of eleven hundred feet was encountered.

Exploratory work is carried on systematically and, as may be inferred by the foregoing descriptions, with a considerable degree of confidence. Whenever possible the ore bodies are reached by means of a tunnel or adit from the hillside, the opening being located in such a way that the drifting may be carried along at right angles to the general direction in which the ore bodies are believed to lie. This direction being approximately north and south over much of the siliceous area, the exploratory tunnels run generally nearly east and west. If the lower contact ores are being searched for, the workings lie immediately upon the lower quartzite. On the higher levels local conditions govern the horizon to be explored. Where access to quartzite by means of tunnels from the surface is not convenient or possible, shafting is resorted to. In this way "sinking to quartzite" has become a common term among the mining men. By means of preliminary surveys the approximate thickness of the rock series to be penetrated may be learned and the amount of work required to reach quartzite estimated with reasonable accuracy. Quartzite being reached, the exploratory work in the form of east-west drifts is prosecuted the same as along tunnels or adits entering from the hillsides.

The Cambrian siliceous ores are classified as blue or un-

oxidized ore and red (or brown) or oxidized ore, the difference being that the red ore represents the weathered phase of the blue ore, the disseminated particles of iron oxide in the form of hematite (red) or limonite (brown) giving the color to the weathered material. No very definite rules can be formulated with reference to the relative position of the two sorts of ore. Naturally the weathered ore is found most abundantly near the outcrops or in those mines having a thin covering, while the blue ore is in larger proportion at considerable depths. In many places, however, doubtless due largely to local structural conditions, red ore and blue ore occur intimately associated apparently without regularity of any kind. Frequently the ore breaks up into rounded or nodular blocks with concentric shells, the inner more consolidated portions being not infrequently made up of blue ore, while the outward shelly portions are red or brown. This is known as "kidney" ore and indicates in an excellent way that the red or brown ore is only a weathered form of the blue.

Sometimes the ore partakes of the nature of a soft clay. Certain mines near Portland have yielded considerable ore of this character, and many mines elsewhere have produced it in greater or less quantity. Recently Mr. Blatchford, of the Golden Reward company, collected an extensive series of such soft ores from the Ruby basin mines. Their color ranges from almost pure white through various shades of gray, yellow, red and brown to black. One peculiar bluish gray variety, known as "miners' wax," is distinctly soapy in appearance and feel, soft when first taken from the mine, but, like most of the other varieties, becomes hardened after exposure for a few days to the air. The origin of these clay ores is not known, but they seem in general to represent a highly weathered condition of the porphyry. The values which they contain are not infrequently above the average.

Iron is present in the ore chiefly in the form of hematite or limonite in the oxidized ores and pyrite in the unoxidized ores. Sulphur is always present in the unoxidized ores. It occurs generally in combination with iron as pyrite, and

occasionally with calcium as gypsum, with antimony as stibnite, and with barium as barite. Calcium and magnesium are rarely absent. Fluorite is abundant in a few localities. Copper minerals are not infrequent. Tellurium is present, it having been first observed by Dr. Richard Pearce in ore from the Welcome mine at Terry. Prof. F. C. Smith has given some attention to its effect in metallurgical processes. Silver is present in varying quantity, its average being about two ounces to the ton of ore.

Prof. F. C. Smith gives analyses for the oxidized and unoxidized ore as follows:*

<i>Oxidized (Red Ore).</i>	
	Per Cent.
Silica	84.45
Alumina.....	4.07
Ferric oxide.....	7.28
Calcium oxide.....	.85
Magnesium oxide.....	.25
Sulphur trioxide.....	3.71
Tellurium.....	8.426 oz. per ton.
Gold.....	.574 oz. per ton.
Silver	2.875 oz. per ton.
Total.....	100.61

<i>Unoxidized (Blue Ore).</i>	
	Per Cent.
Silica.....	68.748
Alumina.....	3.072
Iron.....	13.289
Sulphur	11.728
Gypsum .....	.833
Fluorite.....	.784
Phosphorus pentoxide.....	.842
Tellurium.....	4.03 oz. per ton.
Gold.....	.325 oz. per ton.
Silver	10.55 oz. per ton.
Total.....	99.296

The typical ores are reorganized sandstones and shales, which in their unchanged condition carry a greater or less

* Smith, F. C. The Potsdam Gold Ores of the Black Hills of South Dakota. Am. Inst. Min. Eng., Trans.

amount of calcium and magnesium carbonates. The rock when massive and not sufficiently auriferous to be of value is commonly known among the miners as "sand rock." The transition between the sand rock and the underlying quartzite is sometimes sharp and sometimes gradual. Irving states that in those localities where the transition is gradual the sand grains increase in abundance as one goes downward, until dolomite appears merely as a cement.

The ore bodies represent chemical replacements of the lime-magnesia material by siliceous solutions carrying gold, the deposition being a metasomatic interchange of silica, pyrite, etc., for the carbonates of lime and magnesia, whether the latter are present only as a cement or as the body of the rock. The carbonates doubtless acted as the precipitating agents. The source of the gold was evidently from the rocks beneath the Cambrian deposits. Whether or not it all came from the Algonkian metamorphic rocks or partly from still deeper sources is uncertain.

Mr. J. D. Irving outlines the history of the formation of the ore bodies as follows: *

First occurred the intrusion of the older quartz-porphyrries, which produced much shattering. Contemporaneous with these there may have been a certain amount of ore deposition, but not that to which the main siliceous ore bodies owe their origin. Later the eruption of the phonolites took place, cutting and shattering the older eruptives and adding to the number of fissures in the sedimentary rocks. Subsequent to all of these intrusions, and probably separated from them by only a brief interval of time, came a long period during which heated solutions containing fluorine and silica and other powerful mineralizers gradually replaced the carbonate of lime in the more soluble strata of the Cambrian. The chemical activity of these solutions was increased by the heat and mineralization derived from the newly injected phonolites. They passed up through the Algonkian slates and schists, becoming much enriched by the leaching out of the gold from the rocks. Finally they reached the very calcareous and porous rocks of the Cambrian, and by a metasomatic interchange, produced the horizontal ore bodies that are found to-day.

Many difficulties were encountered in the earlier treatment of these ores, hence the history of their development

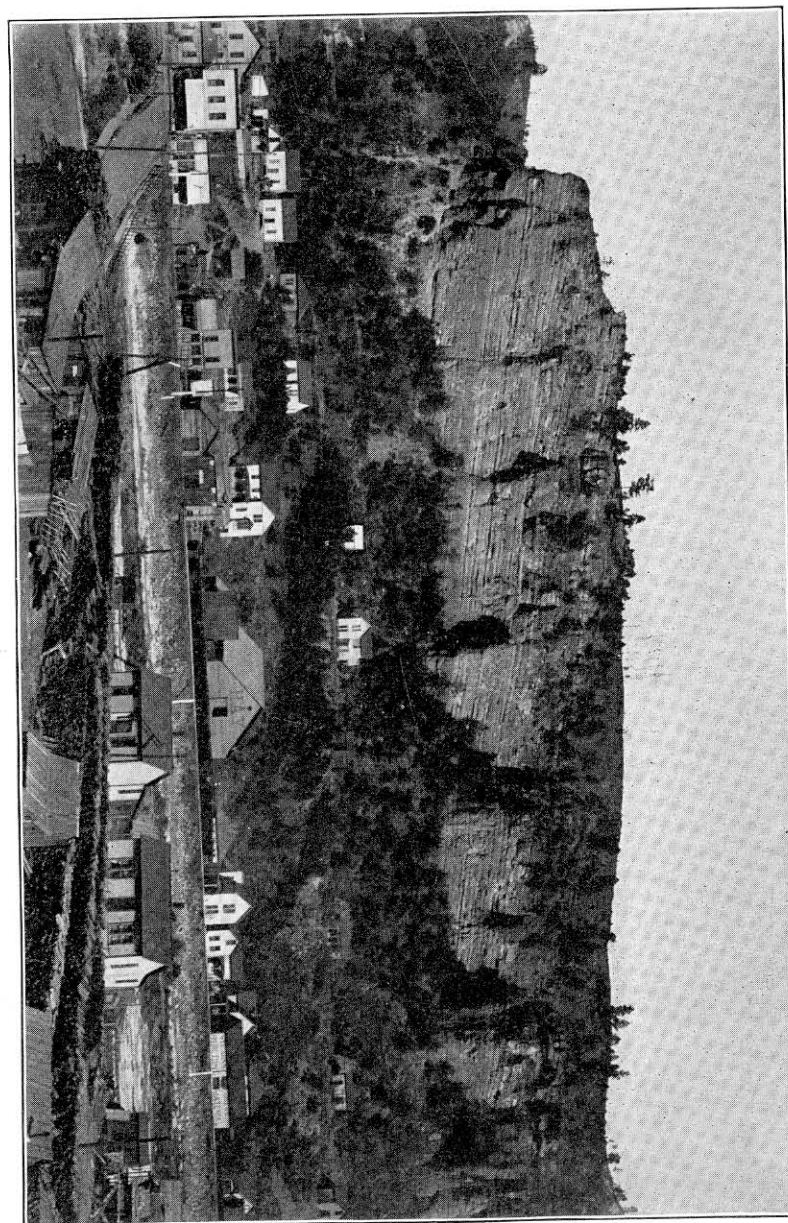
* A Contribution to the Geology of the Northern Black Hills. Annals N. Y. Acad. Sci., Vol. XII, 1899, No. 9, p. 311.

is a matter of some interest. Prof. Smith gives the following facts in this connection:

The history of the Potsdam ores commences in 1877, when Mr. A. J. Smith, of Portland, South Dakota, located the Empire mine on Green mountain and later the Trojan, Perseverance and Indispensable in the same vicinity. In 1879 the first engine was erected to supply power for the treatment of these ores; with it an arrastre was run upon ores from the Empire mine averaging about \$35 per ton. The saving in precious metals was little or nothing, and the attempt was discontinued after about two months. In 1880 the Portland Mining company, owning the Portland, Gustavus and Pilgrim mining claims, built a mill (which still stands idle near the old town of Portland) for the treatment of these ores by pan-amalgamation; later this company purchased the Empire, Trojan, Indispensable, Perseverance, Folger and Olive claims. Pan-amalgamation saved about 50 per cent of the silver and 30 per cent of the gold; and various other processes, such as "free-milling," kiln-roasting and chlorination, and cyanide lixiviation, were tried without success. In 1883 the Welcome Mining company passed through a similar history of unfortunate metallurgical experiment upon their property near the head of Fantail gulch. In 1886 the Buxton mill was built by the Buxton Mining company, and experiment made there by Mr. O. P. Ankeny by the use of bromine seemed to have stopped just short of success, probably on account of disadvantages which, at the present date, would not surround the experiment. About this time the siliceous ores were successfully treated by the Plattner process in the metallurgical department of the School of Mines. In 1889 the Golden Reward Gold Mining company erected a plant in Deadwood for the treatment of the Potsdam ores by barrel chlorination, commencing in April, 1891, with a capacity of fifty tons per day. In 1890 the Deadwood and Delaware Smelting company built the small experimental smelting plant in Deadwood, which has since grown so largely. Two years later, or in 1892, a small cyanide plant was erected in Deadwood by the Black Hills Gold and Extraction company; and in November, 1895, the Kildonan Milling company started chlorination works at Pluma [a short distance from Deadwood] with a capacity of about seventy-five tons per day.*

Prior to the erection of the Deadwood and Delaware smelter (now the Golden Reward smelter) and the Golden Reward chlorination plant (destroyed by fire in 1899), both of which proved successful, siliceous ore assaying less than

* The Potsdam Gold Ores of the Black Hills, Am. Inst. Min. Eng., Trans., Vol. XXVII, 1897.



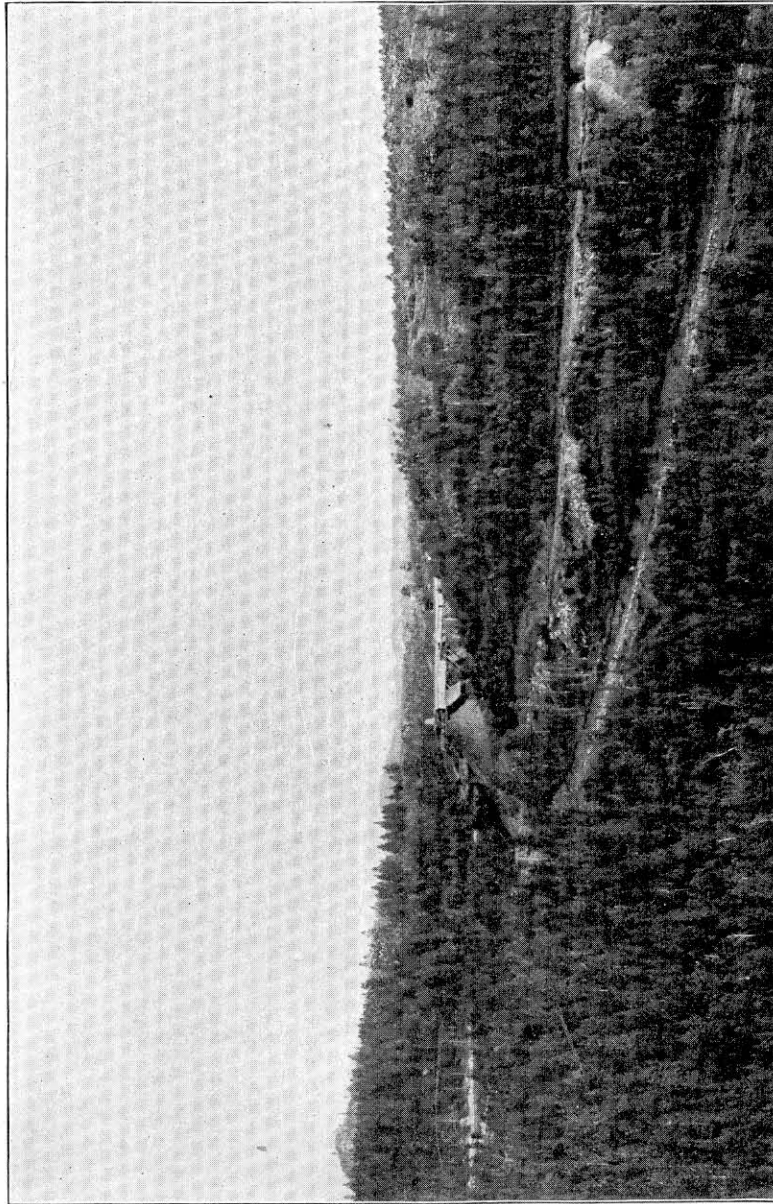
MIDDLE CAMBRIAN SHALES AND SANDSTONES, DEADWOOD.

about \$30 a ton could not be utilized. By 1894 the processes had been sufficiently perfected to allow for the profitable treatment of \$15 ore. Since the recent introduction of the cyanide process, ores much below \$15 have proven profitable and in favorable instances ores as low as \$3 have yielded fair return.

CARBONIFEROUS SILICEOUS ORES.—Gold was discovered in remunerative quantities in the Carboniferous limestone near Ragged Top mountain in 1896. A shaft had been sunk in 1886 on the Silver Ridge property north of the mountain, the rock there having something the appearance of the silver-bearing rock at the Iron Hill mine to the northeast, but nothing of permanent value was found and the shaft was abandoned. Ten years later, however, a fortunate assay of material found three hundred yards west of the Silver Ridge shaft gave a value of \$200 in gold to the ton. Other good ore was quickly found, and a local boom immediately followed.

The discoveries of importance referred to were made on detached boulders or fragments, but further prospecting located the ore in long fissures or "verticals" both to the north and the south of Ragged Top, but chiefly to the north on what is known as the Dacy or Balmoral flat. These so-called verticals are perpendicular crevices in the massive limestone, partially or wholly filled with a siliceous mass of brecciated limestone containing more or less iron oxide and calcite. Active mining operations were carried on along these verticals, seven in number, during the years 1896-97 and then ceased, the ore becoming too lean to be profitably worked.

The greatest thickness of the verticals at the surface was approximately ten feet, but all are said to have become narrower with depth. The average depth of ore of sufficient value to work—at that time approximately twenty dollars in gold to the ton—was about sixty feet, although the Balmoral and the Dacy considerably exceeded this depth. The Dacy vertical, the largest producer, has been traced along the surface a distance of two thousand feet or more. Its direction is N 35° W and the general trend of



STEWART MINE ON LOWER QUARTZITE, NEAR TERRY

the other verticals is about N 45° W. The walls are illy defined, lateral enrichments sometimes occur, and the ore when not brecciated is scarcely different in appearance from the lean or barren limestone enclosing the ore body. The ore is usually slightly darker, however, and is always harder, owing to the presence of the silica. Professor Smith gives the following analysis of Dacy ore:*

	Per Cent.
Moisture.....	0.110
Volatile matter.....	0.802
Silica.....	90.990
Alumina.....	2.970
Ferrous oxide.....	3.024
Calcium oxide.....	1.138
Magnesium oxide.....	trace
Tellurium.....	29.26 oz. per ton.
Gold.....	17.34 oz. per ton.
Silver.....	1.21 oz. per ton.
Total.....	99.034

A few miles north of Ragged Top mountain on the Cleopatra property a small vertical has been found in the limestone apparently similar in every way to those found on the Dacy flat. This has not been exploited.

The Ulster mine, situated a little to the east of the Dacy flat proper, shows a different occurrence of ore, the origin, however, being evidently much the same as those of the Dacy type. I quote from Mr. Irving concerning the nature of this deposit:

In the Ulster mine the ore occurs in contact zones between the limestone and a very irregularly intruded mass of porphyry. This is cut by a dike of dense green phonolite, and the ore seems to have resulted from the silicifications of brecciated limestone, which has been fractured by the intrusion of Twin peaks and other porphyry bodies in the Cambrian below. Brilliant purple fluorite occurs in great quantities. The ore is irregularly distributed. It may thin to a mere streak, and again open out to a very large and thick mass. The values obtained are very high, running frequently up to \$150 per ton, and in one instance \$1000 per ton.†

* The Potsdam Gold Ores of the Black Hills, Am. Inst. Min. Eng., Trans., Vol XXVII.

† A Contribution to the Geology of the Northern Black Hills. N. Y. Acad. Sci., Annals, Vol. XII, 1899, No. 9, pp. 313-314.

The total output of the verticals north of Ragged Top, including the Ulster, has been estimated at \$250,000. The principal producers have been the Dacy, the Balmoral, the Ulster, the Ragged Top, the Sterner, the Little Bud and the Doyle. No statistics are at hand giving the production of the verticals further south.

After active work upon the verticals had ceased the discovery was made that the massive limestone itself is sometimes impregnated over considerable areas with an encouraging percentage of gold. In several places, particularly to the south and southwest of Ragged Top mountain, it has been learned that with metallurgical processes now available this impregnated material can be treated with profit. The pioneer company in the development of this sort of ore is the Spearfish Gold Mining and Reduction company, their property lying on the high limestone flat between Ragged Top mountain and Spearfish canyon. A 250-ton cyanide plant, built by the company in 1899, continued in successful operation until its destruction by fire in October, 1901. During the past summer the Deadwood Standard Mining company erected a cyanide plant immediately south of the Spearfish company's property, the ore from the two properties being practically identical. Other plants are now in process of erection.

The ore is in close association with intrusions of trachytoid phonolite, the origin of the ore being due to the presence of the igneous rock. A shallow shaft on the Spearfish property cuts through six feet of phonolite with ore above and below, while in a tunnel on the same property the roof is phonolite, the ore lying immediately beneath.

The ore looks much like ordinary gray limestone weathered to a rather soft and porous condition and containing iron oxide and silica. The gold content is not high, but the ore is easily mined and cheaply treated, hence may be worked with considerable profit. On the Spearfish ground where the ore body is most extensively exploited, the ore under favorable conditions of weather is simply quarried in large open pits. Tunnels for underground winter work

have been made, but they nowhere extend far beneath the surface. In the neighboring properties similar conditions of mining and treatment prevail.

One feature of interest in connection with the ore, but which has not received careful study, is the apparent occurrence of the values along well developed or incipient joint planes. The ore demands much less crushing than is generally the case with the more highly siliceous ores, particularly the Cambrian quartzite ores. In some of the Yellow creek mines, however, coarse crushing is sufficient for quartzite, and it is possible that in such instances the gold content is also distributed along the illy disclosed joint planes. This condition of distribution is beautifully shown

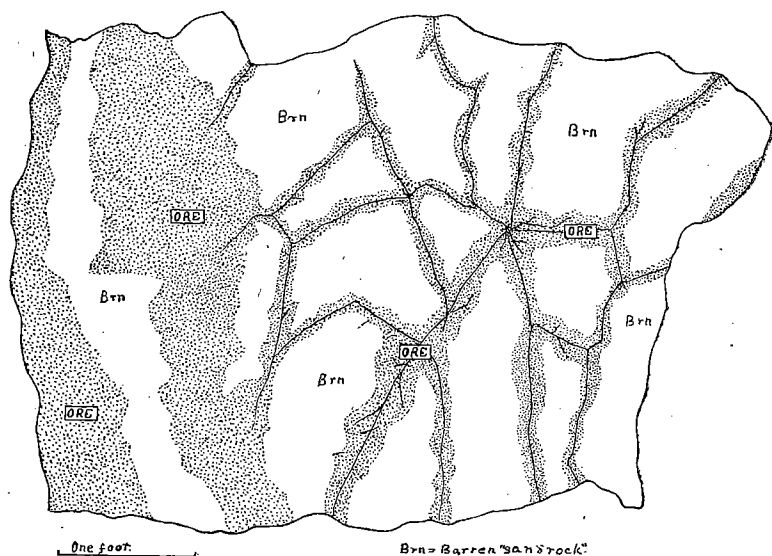


Fig. 4. Ore following joints in the Cleopatra Mine.

on an enlarged scale in one part of the Cleopatra mine as illustrated in figure 4, where the joint blocks are impregnated with gold only along the joint planes.

The origin of the Carboniferous gold ores is practically the same as that of the Cambrian ores. Siliceous solutions

carrying gold have removed original calcite, leaving silica instead, the exchange taking place subsequent to the intrusion of the igneous rocks in post-Cretaceous time. The ore bodies are vertical on the Dacy flat and elsewhere, approximately horizontal in the properties owned by the Spearfish and the Deadwood Standard mining companies, and irregular in the Ulster. The intrusions have affected the country rock differently in the different localities, and the various positions and shapes of the ore masses are simply due to the form and direction of the particular fissure through which the solutions reached the limestone.

PLACER DEPOSITS.—Placer gold is found in the gravel bars of all of the present streams and in the various terraces which line their valleys. Few of these deposits have failed to yield gold in paying quantity, and many have produced handsomely. French and Castle creeks were first successfully prospected, but Rapid creek, Battle creek, White-wood gulch, Spearfish creek and their tributaries followed quickly thereafter. The richer deposits of all of these streams are now either practically exhausted or are in such position with reference to water supply that they can no longer be worked extensively with profit.

Most of the placer gold during the height of the placer mining activity was obtained by the simple methods of panning, rocking and ordinary sluicing. Sluicing was carried on wherever possible, but in many of the gulches flowing water was available in quantity only during the early part of the year while the melting snows and the spring rains were contributing to the volume of the streams. For this reason the light rocker, easily carried or wheeled from one reservoir or pool of water to another, was often utilized. The Rockerville mining camp was especially noted for the large number of these rockers, hence the name of the camp as well as the name of the gulch on which the camp was located. Here by this simple method during the years 1877-79 gold to the amount of approximately one-half million dollars was obtained. Even at the present time the rocker may be seen occasionally in use on this gulch, where fair wages may be obtained by the careful workman, al-

though hampered by the necessity of bringing the gravel from the pit to the water's edge by means of a wheelbarrow.

In general the sluicing was of the most economical nature. Shallow ditches and temporary flumes were made by the individual claim owner or by the combined energies of the several owners of adjoining claims, and the gold separated by the water thus obtained.

In at least three instances hydraulic mining was attempted, namely at Rockerville, near Pactola, and along Battle creek. The Rockerville enterprise, perhaps the most extensive of the three, consisting of the building of a seventeen-mile box flume from a reservoir on Spring creek two miles above Sheridan along a winding and difficult mountain course to the high "dry diggings" near Rockerville, which extend as much as four hundred fifty feet above the bed of Spring creek one and one-half miles to the north, where that stream approaches nearest the deposits. The flume, built by the Black Hills Placer Mining company, was begun in 1878 and was completed two years later at a cost of \$210,000. Operations were carried on for about two years and approximately \$500,000 in gold obtained. Litigation then suspended operations and the flume was abandoned. About the year 1880 the Estrella del Norte company constructed flumes aggregating several miles in length above and below Pactola on Rapid creek, where work was prosecuted for several years with indifferent success. The third effort was made by the Harney Hydraulic Gold Mining company in 1883. In the attempt to secure sufficient water both Grizzly gulch and Battle creek were tapped, the flumes uniting at the mouth of Grizzly gulch and extending as one flume down Battle creek to Mitchell's bar below the present site of Keystone. Some gold was obtained, but this enterprise like the two others was soon abandoned without reaping the return hoped for.

The most noted placer localities were those of Deadwood, Nigger Hill and Rockerville. The Deadwood area (plate 13) included the following important gulches: Dead-

wood (sometimes known as the great bonanza gulch of the Hills), Whitewood, Gold Run, Blacktail and Bobtail. In the Nigger Hill district the principal placer streams were Bear gulch, Potato gulch, Nigger gulch, Sand creek, Poplar gulch and Mallory gulch. The Rockerville area was made up chiefly of a high terrace several square miles in extent, together with the various small gulches leading off from this terrace.

The rich nature of the Deadwood placers was discovered in November, 1875, at which time Discovery claim was located by William Lardner and others on Deadwood gulch a little below the mouth of Blacktail gulch. The Nigger Hill deposits were discovered a few weeks earlier than those of the Deadwood locality, while the Rockerville gold was not found until more than a year later. Many other localities, although not producing so largely as those given, have nevertheless added greatly to the total output.

Some streams of considerable importance lie mostly within areas covered by stratified rocks and have had little opportunity to collect and concentrate gold. Box Elder creek and Elk creek as well as most of the streams south of French creek, are of this class. Concerning the French creek placers over which there has been much disappointment Prof. Jenney says:

I regard the poverty of the French Creek deposits, compared with those afterward discovered on the streams farther north, to be due to a deficiency in the source of supply, owing to the small area drained by the streams, the small amount of denudation to which the ledges in this area have been subjected, and to a want of sufficient grade in the valley to cause concentration of the gold into a pay channel. Had all of the gold diffused through the valley of French creek been concentrated into a narrow lead or pay channel, it would have made claims as rich as the most enthusiastic miner would have desired.*

The high valleys of French creek and Battle creek lie among granites and schists chiefly, while the streams further north traverse areas made up mostly of shales, quartzites and late eruptives, the main trend of the streams in

* Geology of the Black Hills, p. 238.

nearly all cases being across the general strike of the up-turned rocks. The character of the rocks has much to do with the nature of the stream valleys and therefore of the gold concentration. The schists give way to broad valleys and parks checked here and there by peaks and ridges of harder rocks; while the quartzites and siliceous slates, by their greater resistance to weathering action, present steep slopes and precipitous canyons, along the bottoms of which the energetic streams must thread their way.

Of all of the streams Rapid creek leads in the areal extent of its placer deposits. For forty miles these deposits line its course and range in successive steps from the creek bed to various heights above. Much of the gold is in fine particles, particularly below the union of Castle and Little Rapid creeks, and much of the placer material is made up of heavy boulders, so that it is not easy to secure the values.

The gold lies chiefly upon or near the bed rock, although occasional streaks of value are found higher in the deposits, the deposits being made up of a heterogeneous mixture of sand, pebbles, boulders, clay, etc., collected from the surrounding country rocks.

The gold from the various streams differs slightly in color and other physical characters and in chemical composition, but in all cases a high percentage of purity is shown. The following analyses indicate this fact:

	Gold.	Silver.	Base Metal.
Spring Creek*.....	937.8	45.9	16.3
Spring Creek*.....	946.4	50.4	3.2
Spring Creek†.....	934.	49.	17.
French Creek†.....	933.	55.	12.
Rapid Creek †.....	940.	60.	....
Deadwood Gulch†.....	907.	93.	....

Castle creek and Battle creek have yielded considerable coarse gold, as have also the many streams of the northern Hills, particularly those of the Nigger Hill district. The following record of the largest Black Hills nuggets has been collected with care and, although incomplete, is believed to be correct as far as given:

* Jenney, W. P. Geology of the Black Hills, pp. 249-250.

† Scott, Samuel. Map of the Black Hills of South Dakota and Wyoming, etc., 1897.



DEADWOOD.
Tarry Peak in the Distance.

Nugget on Discovery claim, Bear gulch, found in 1875 by Portigee Frank, value \$18.

Nugget on Montana bar near Sheridan, 1875, name of finder unknown, value \$23.

Nugget on Claim No. 32, Bear gulch, 1876, by John McTigue, value \$51.

Nugget on Claim No. 28, Potato creek, 1876, by Frank Mantz, value \$146.

Nugget on Claim No. 23, Bear gulch, 1877, by E. St. John, value \$57.

Nugget on Claim No. 12, Potato Cr., 1877, by Frank Mantz, value \$90.

Nugget on Claim No. 31, Bear gulch, 1877, by E. St. John, value \$56.

Nugget on Mallory gulch, 1878, by John Majors, value \$81.

Nugget on Centennial gulch, 1878, by Peter Thorson, value \$120.

Nugget (the largest ever found in the Black Hills) on Claim No. 37, Bear gulch, 1879, by "Doc" Wing, value \$465.

Nugget on Claim No. 16, Bear gulch, 1879, by David Gillespie, value \$54.

Nugget on Sand creek, 1881, by William Bell, value \$78.

Nugget on Claim No. 12, Bear gulch, 1882, by E. St. John, value \$51.

Nugget on Mallory gulch, 1883, by M. R. Hydliff, value \$117.

Nugget on Claim No. 5, Bear gulch, 1887, by Jas. McCoun, value \$53.

Nugget on Ruby gulch, 1890, by Samuel Moll, value \$27.

Nugget on Sand creek, 1893, by M. R. Hydliff, value \$63.

Nugget on Poplar gulch near Inter Ocean mine, 1893, by Messrs. Heavirlian and Mulheisen, value \$57.

Nugget on Lightning creek, 1899, by Lee and Chas. Carr, value \$43.

Most of these nuggets were well rounded pebbles of gold almost or quite free from extraneous matter. The \$465 and the \$117 nuggets were exceptions, a considerable part of their volumes being taken up by quartz.

Associated with the gold in the placers are garnets, hematite and limonite pebbles, columbite, tantalite, cassiterite and other less noticeable minerals. The garnets are abundant in most of the streams, particularly in those of the central and southern Hills. Columbite and tantalite are not uncommon in the Harney peak region and are abundant in the Nigger Hill district. Cassiterite occurs in pretty much the same streams as the columbite and tantalite, it being found in such abundance in the Nigger Hill gulches as to have furnished considerable annoyance to the miners before its nature was learned. It is now a source of not a little profit. Platinum, although diligently searched

for, appears not to have been found. Professor Carpenter mentions the finding of remains of the mammoth, *Elephas primigenius*, and recently a well worn tooth found near Hayward was presented to the School of Mines.

TAILINGS.—It is well known that in the various processes for treating ores more or less of the values fail of extraction. Occasionally in the past this has been a matter of consequence, but within recent years careful study of the metallurgical needs of the various ores has greatly lessened this loss.

During the past two years a small cyanide plant has successfully treated the tailings of the now dismantled Rapid City chlorination works, and at the present time a small plant is treating the silver-bearing tailings from the old Iron Hill works near Carbonate.

Attention has also been directed to the vast quantities of tailings from the Homestake mills scattered along the bed of Whitewood creek for a distance of several miles below Lead. Previous to the installation of the great cyanide plant near the mills much of the concentrates were saved and smelted, but considerable values escaped into the creek. This material has been more or less concentrated by the ordinary stream action, but in a few instances special effort has been exerted to collect it in localities favorable for future operations. Plate 16 gives a view of a large body of these tailings collected at Pluma, between Lead and Deadwood. During the past summer four cyanide plants have treated these tailings in as many different places on Whitewood creek.

METHODS OF TREATMENT.—The gold ores of the Black Hills, as indicated on the previous pages, are free-milling, partly free-milling, and refractory.

The treatment of the free-milling ores present few difficulties, the ordinary amalgamating stamp mills securing the values in a highly satisfactory manner. The refractory ores are more complicated. Other things besides the refractory nature of the ores, such as richness, conveniences for shipping, competitive prices for treatment, etc., enter into the selection of methods to be adopted.

At the present time two methods of treatment prevail, namely, smelting and cyaniding. Chlorination processes entered into the earlier treatment, large plants having been erected at Pluma, Rapid City and Deadwood. None of these are now in operation.

For more than ten years the Golden Reward smelter (plate 14)—formerly known as the Deadwood and Delaware smelter—of Deadwood, has been successfully treating large quantities of medium and high grade siliceous ores, chiefly from the Bald Mountain-Ruby Basin region. In addition to this smelter in Deadwood, another large one with extensive modern improvements is now building in Rapid City.

Recently much interest has been shown in the development of the cyanide process, the low-grade oxidized siliceous ores readily yielding their values by this method.

At the close of the year 1901 six cyanide plants were in successful operation on various ores, the largest being the Homestake tailings plant with a capacity of thirteen hundred tons daily. Another at the Cleopatra mine is shown in plate 17. Eight other plants were completed, but of these two had been destroyed by fire, one was dismantled, and five were idle. Six other plants are now in course of erection.

The partly free-milling ores combine the methods of treatment of the free-milling and the refractory ores. Such of the values as are free are extracted by amalgamation and the concentrates are sent to the smelter.

Individual ores present their peculiar difficulties, and the details of treatment in each plant vary in many ways, but it is no purpose of this paper to enter into a description of the various methods. Most of the literature on the subject is readily accessible to those interested.

OUTPUT.—In a short paper entitled "The Production of Gold in the Black Hills," published in *The Aurum*, Vol. 1, No. 1, Rapid City, South Dakota, I have considered the merits of various estimates of the output of gold from the Black Hills. Without entering here into the details of that paper, it may be said that in the light of all available

sources of information the following series of statistics expressed in round numbers appears to represent with fair accuracy the annual gold output:

Gold Output of the Black Hills.

Year.	Output.	Year.	Output.	Year.	Output.
1875	\$ 10,000	1884	\$3,300,000	1893	\$4,000,000
1876	1,400,000	1885	3,200,000	1894	3,900,000
1877	2,000,000	1886	2,700,000	1895	3,900,000
1878	3,000,000	1887	2,400,000	1896	5,000,000
1879	3,600,000	1888	2,600,000	1897	5,700,000
1880	4,200,000	1889	2,900,000	1898	5,700,000
1881	4,000,000	1890	3,200,000	1899	6,500,000
1882	3,300,000	1891	3,600,000	1900	6,200,000
1883	3,200,000	1892	3,700,000	1901	7,000,000
Total					\$100,210,000

FUTURE PROSPECTS.—The annual gold production of the Hills, as indicated in the above table, has increased almost steadily for a number of years. In the earliest history of the Hills, placer deposits furnished the chief output and were practically exhausted before the cement ores became of importance. The cement ores in turn declined almost co-incidentally with the rising influence of the Homestake belt. The Homestake belt continued for several years the only extensive producer, the quartz vein and other mines generally showing little disturbance of the annual output.

With the discovery of successful metallurgical processes by which the values in the siliceous ores could be saved, a new and important factor in the gold production was introduced. The tendency has been to continually lessen the cost of treatment of the siliceous ores, so that lower grades of ore could be utilized. Thus it has happened that the siliceous ore mines now rival the Homestake in output, even though the latter has greatly enlarged its working equipment. As a consequence, two constantly growing factors are at present aiding each other in swelling the production, while never before has there been so great activity in the mines not classed with the siliceous ore and the Homestake mines.

Individuals or companies with sufficient means to properly prospect for ore bodies, and influenced by intelligent study of geological conditions, are constantly disclosing abundant values in localities formerly supposed to be barren. Indeed it may be said that new ore bodies of low and high grade are revealing themselves as rapidly now as at any time in the history of the region, and there is every reason to believe that for many years to come the annual output of gold will continue enhancing in value.

COPPER.

The first prospectors in the Black Hills noted the presence of copper, and a few claims were early located. Among the earliest of these were the Blue Lead (pronounced *Lead*) one mile east of Sheridan, the first county seat of Pennington county; and the Black Hills Copper company's property six miles west of Rochford, also in Pennington county. For many years little more than assessment work was done on any of the properties located, and, although considerable interest has centered around some of the claims, none were exploited sufficiently to establish their value.

The constant demand for copper ore at the local smelters for use in the reduction of the refractory gold ores, and the enhanced value of native copper during the past two or three years, have greatly heightened the interest in the copper possibilities of the Hills. Many new claims have been located, abandoned claims have been relocated and worked with greater energy, and in a few places many thousand dollars have been spent in the effort to find deposits of positive value.

The deposits, in so far as surface conditions seem to indicate them, are numerous, extensive and well distributed, but as yet none have become steadily productive. Some study has been made of their relative position, and while the properties located are commonly spoken of as being roughly arranged along two north and south belts, one near the central portion of the metamorphic area and the other near its western edge, it is doubtful if this relation-

ship is an important or even a real one. Beginning with the Blue Lead near Sheridan on Spring creek and going northward, we find near Pactola on Rapid creek the Poisoned Ox, the Copper Reef and the Copper Glance. On the county line near the head waters of Bogus Jim creek is the Rio Tinto. Further north, one-half mile southeast of Nemo on the Box Elder is the Holy Fright, and three miles northwest of this is the Copper Castle. The line, then gradually deflecting more to the west, crossing Elk creek near Elk Creek station, crosses Windy flats north of Perry, then by rather obscure outcroppings reaches Deadwood, within the city limits of which considerable exploratory work has been done. Occasional prospects are reported, extending from Deadwood southwestward to the county line, near which are grouped the Copper Cliff, the British American and the Black Hills. These lie near the South Fork of Rapid creek northwest and west of Rochford. Southward two or three miles is the Reynolds property and still further south the Palmer property. West of Hill City is the Mastiff, and beyond this southward are the Truax and the Vigilante. Other prospects of more or less interest lie along the lines indicated, while some have been found having no apparent relation to these lines.

Practically all of these properties carry a copper stained gossan, some of them showing it in great quantity and not infrequently with a considerable amount of copper. In sinking through this gossan a leached material known as "ash" is reached. This is a soft black decomposed slate quite free from minerals of value.

Thus far no one has gone through this ash, but the Black Hills Copper company is now working to this end, their inclined double-compartment shaft of eight hundred feet having penetrated beneath the surface to a perpendicular depth of more than four hundred feet. At the Blue Lead a tunnel cutting below the surface outcroppings a perpendicular distance of more than six hundred feet, has penetrated the unchanged slates charged with iron and copper pyrites. Thus, notwithstanding the great amount of work done, the lower limit of the ash is not yet reached and the

conditions in the zone between the ash and the sulphides remain to be learned.

The Black Hills copper deposits are frequently compared with the Ducktown, Tennessee, deposits and apparently with much reason. The country rock is much the same in general character, the structure is not greatly different, the general dip of the veins approximately the same, the gossan or iron hat in each instance well developed, the leached and decomposed slates equally prominent, and the sulphides below contain more or less copper. Nickel is said to be present. The chief similarity to be yet established, if such similarity exists, is in the intermediate zone not yet penetrated in the Black Hills, but which, being the horizon at which were found the valuable sulphide enrichments of the Ducktown deposits, holds perhaps the key to the successful development of the Black Hills deposits. That such enrichments exist here is quite possible, and the indications are that they may be found.

Mr. W. H. Weed, of the United States Geological Survey, has recently set forth in a very clear manner the general conditions governing the enrichment of mineral veins by later metallic sulphides, and, while not including references to the Black Hills deposits, the evident application to this region of many of the facts presented by him makes his paper one of particular value at the present time to those interested in the development of Black Hills copper properties. He indicates how the leaching of a relatively lean primary ore, commonly by surface or descending waters, but occasionally by deep-seated waters, will supply the material in solution for such enrichments; how the unaltered sulphides, especially pyrite, will induce precipitation; how the material precipitated is crystalline; how a number of mineral species are commonly formed, and are now forming, in veins by such reactions; and how such minerals deposited in quantity may form ore bodies of considerable size (bonanzas) or may be disseminated through the lean primary ore in strings and patches, thus enriching the ore body as a whole and even making a former low grade body of sufficient value to work. Concerning the

chemical reactions involved in the leaching of the gossan zone he says:

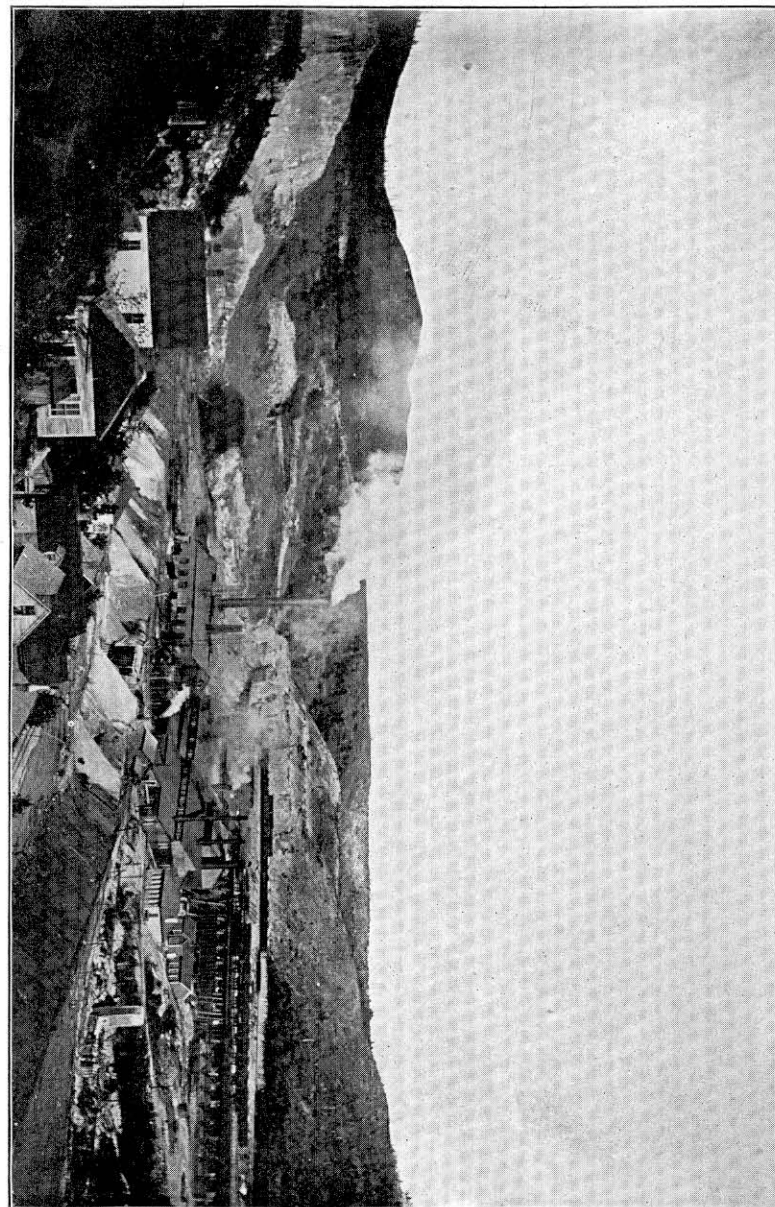
Surface waters descending through the relatively porous and open textured gossan of a vein are normally oxidizing, and on passing downward usually attack the unaltered sulphides and deepen and extend the zone of the gossan. As the waters descend they are robbed of their oxygen by the sulphides which they decompose, and percolating further downward the waters which at first were strongly oxidizing in character are now charged with various salts and frequently with free sulphuric acid. They are still descending waters of surface origin, but have lost all the characters commonly ascribed to surface waters. This change is, of course, due to the reactions involved in the changing of the vein minerals to gossan. The common metallic sulphides of veins are pyrite, pyrrhotite, chalcopyrite, tetrahedrite, enargite, bornite, galena (with which quartz is most commonly associated as a gangue mineral) and a little less commonly calcite and other carbonates, and barite, etc. The changes by which this mixture is converted into a mass of porous, more or less pure limonite are briefly as follows: the pyrite alters to a mixture of iron sulphates and sulphuric acid, which, reacting on more pyrite, eventually forms a mixture of hydrated oxides (limonite ores). The reactions commonly assumed are as follows:

1. $\text{FeS}_2 + \text{O}_3 + \text{H}_2\text{O} = \text{FeS} + \text{H}_2\text{SO}_4.$
2. $\text{FeS} + \text{H}_2\text{SO}_4 = \text{FeSO}_4 + \text{H}_2\text{S}.$
3. $\text{FeS}_2 + \text{O}_2 + 2\text{H}_2\text{S} = \text{FeS} + 2\text{H}_2\text{O} + 3\text{S}.$
4. $\text{S} + \text{O}_3 + \text{H}_2\text{O} = \text{H}_2\text{SO}_4.$
5. $2\text{FeSO}_4 + \text{O} + \text{H}_2\text{SO}_4 = \text{Fe}_2(\text{SO}_4)_3 + \text{H}_2\text{O}.$
6. $\text{FeS} + \text{Fe}_2(\text{SO}_4)_3 = 3\text{FeSO}_4 + \text{S}.$

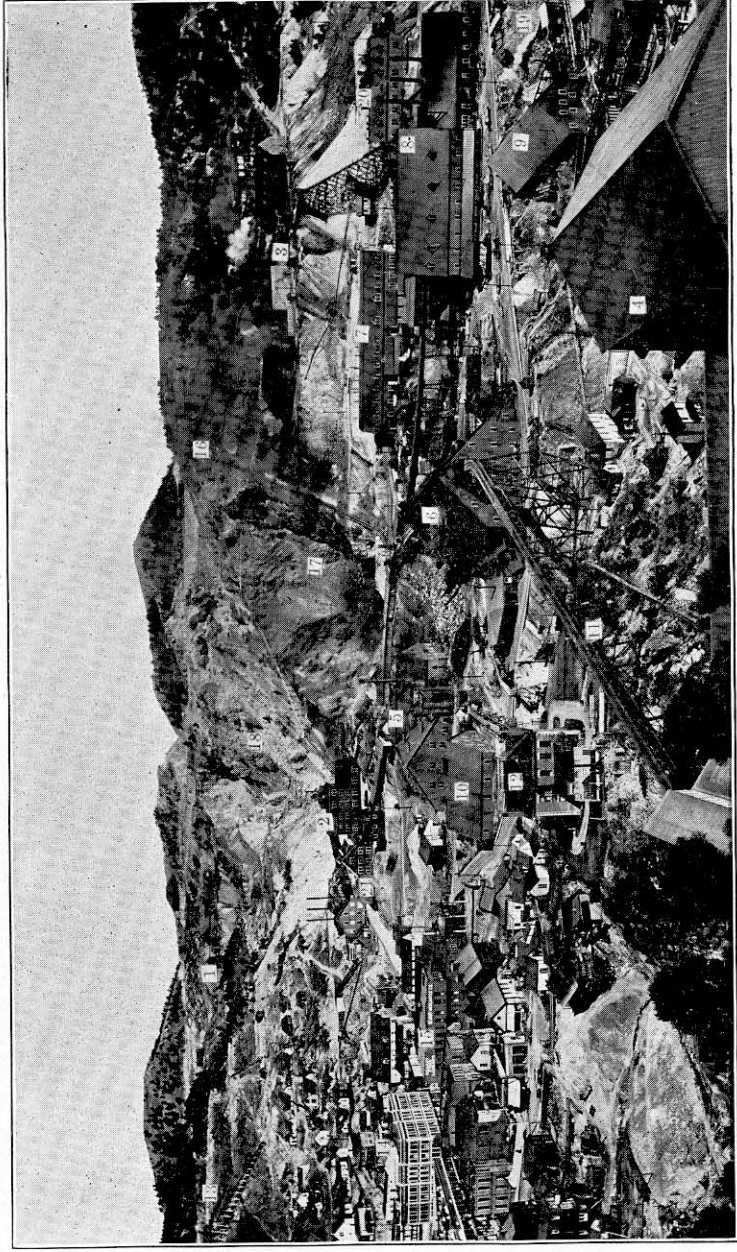
Pyrrhotite, if present, is attacked as in the second equation given.
 * * * * Chalcopyrite being Cu_2S , Fe_2S_3 , the iron sulphide molecule yields more readily to attacking solutions of ferric sulphate (which by hydrolysis are acid) than the cupric sulphide, and the iron is removed and Cu_2S left as the amorphous powder seen.
 * * * * If the amount of ferric sulphate present is relatively small, copper oxide and carbonates will be formed in the lower part of the gossan and in cracks and fissures in the underlying sulphide ores, be they original or secondary.*

The amount of copper ore thus far produced in the Black Hills has been very small. On several properties where extensive work has been done, and from which few ship-

* Weed, Walter Harvey. Enrichment of Mineral Veins by Later Metallic Sulphides. Bulletin of the Geological Society of America, 1900, Vol. II, pp 179-206.



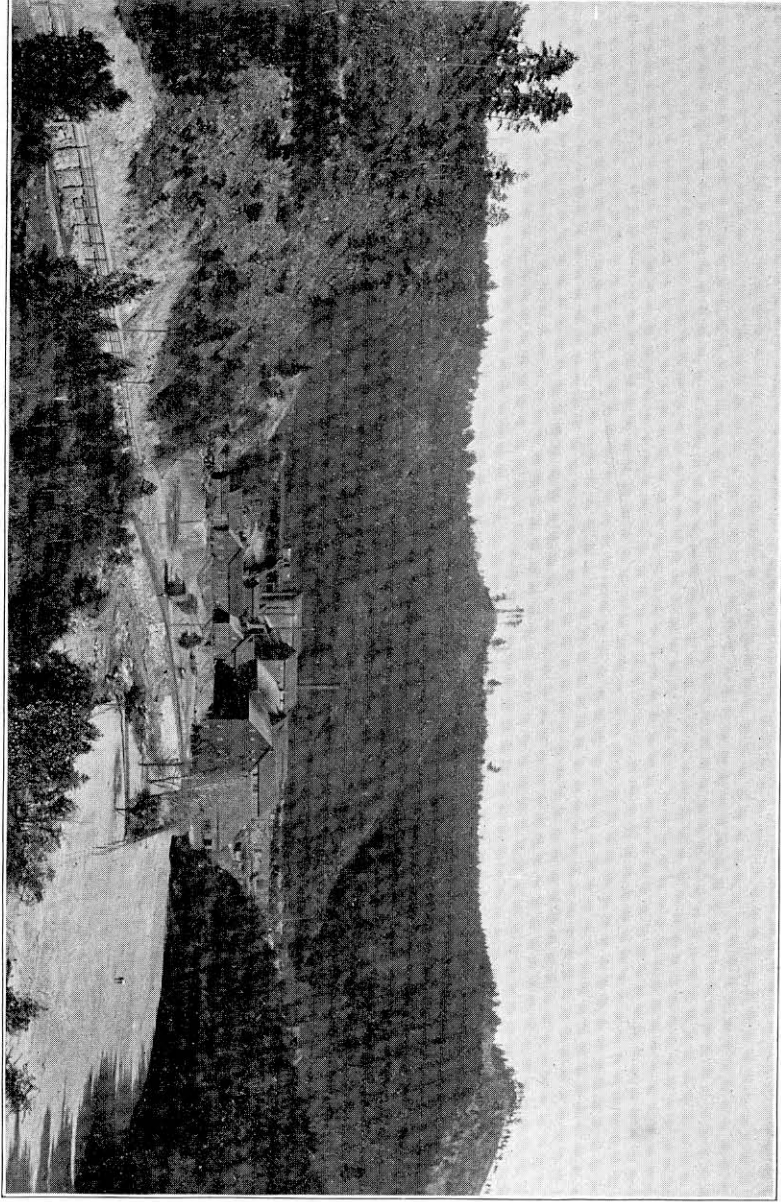
THE GOLDEN REWARD SMELTER, DEADWOOD.
 Formerly known as the Deadwood and Delaware Smelter.

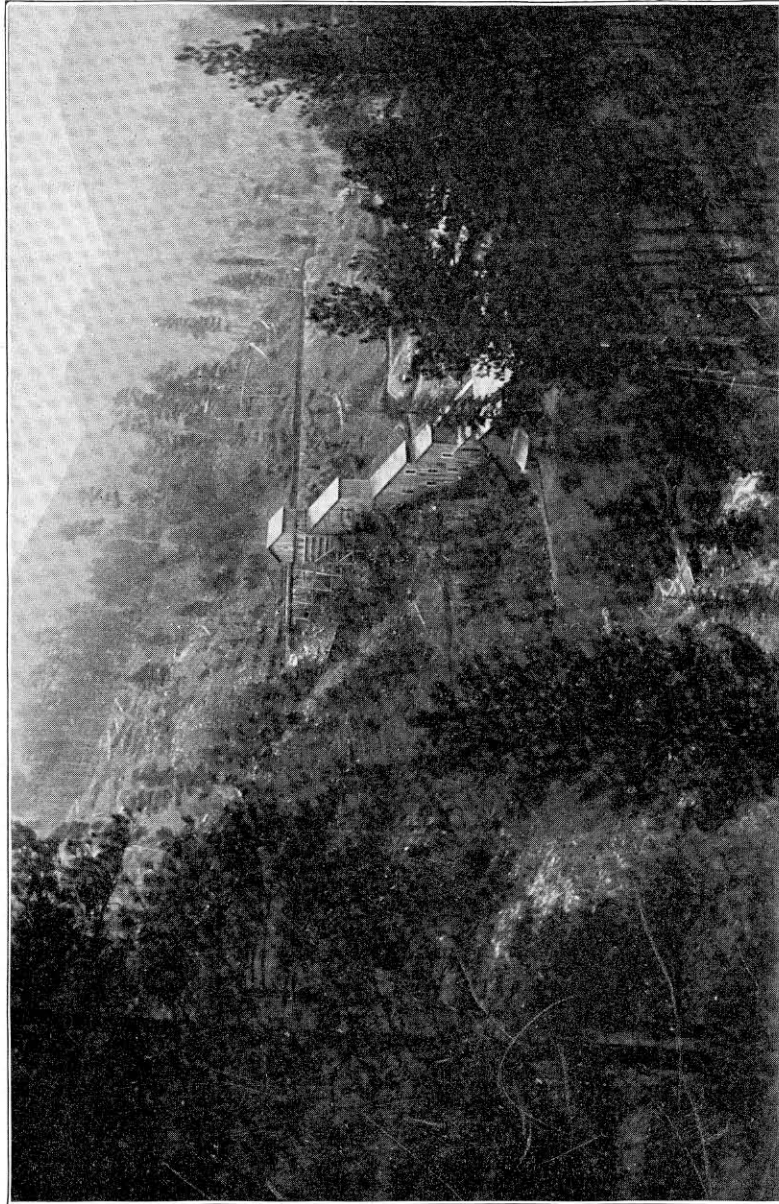


HOMESTAKE MILLS, HOISTS AND OPEN CUTS, AT LEAD.

- | | | |
|---------------------------------|--|--------------------------------------|
| 1. Highland hoist and saw mill. | 13. Cool chute. | 17, 18. Open cuts. |
| 2. Golden Star hoist. | 14. Hotel Smead. | 19. Old experimental cyanide plant. |
| 3. Old Abe hoist. | 15. Office, Hearst free library and company store. | 20. Shop. |
| 4. Ellison hoist. | 16. Wood chutes. | 21. Miners' bath and dressing rooms. |
| 5. Homestake mill. | | |

THE KILDONAN CHLORINATION PLANT, PLUMA.
Deposit of Homestake Tailings in front on the right.





THE CLEOPATRA MINE AND CYANIDE PLANT, SOJAW CREEK, NEAR CARBONATE.

ments have been made, the select ore heaps represent considerable value, but the chief object has been the exploitation of the properties rather than the immediate mining of ore. Occasional shipments are made for the purpose of testing the quality of the ore or to secure funds for defraying the running expenses of development work, the smelters willingly purchasing the material for fluxing purposes, but aside from this the ore has not been utilized.

IRON.

Iron ore bodies of some apparent importance are found in various places within the Hills. Freight rates have prevented the extensive development of these ore bodies, and, except in the case of two or three deposits, almost nothing has been done toward learning their nature and extent. Small quantities of ore have been occasionally used for fluxing purposes by local smelters, and in 1893-94 one hundred sixty-five cars of ore were shipped from Nahant to the smelters at Omaha and Kansas City.

Hematite is abundant on Box Elder creek. Concerning these deposits Newton says:

On Box Elder creek, a ridge some 400 feet in height is composed of a vast deposit of siliceous hematite, which was estimated to be from 800 to 1000 feet in thickness across the upturned strata. Occasional bands of almost pure specular hematite several inches in thickness are found in the mass with frequent layers of highly crystallized micaceous hematite. The body of the ferriferous strata, however, is highly siliciferous and entirely useless as an iron ore, consisting of thin strata an inch or less in thickness of specular hematite alternating with siliceous slate or with pure white quartz in seams or irregular masses, the whole presenting a remarkable resemblance to the siliceous banded hematite of the Huronian of the Lake Superior region. In other localities on the same creek hematites were also found in the siliceous slates, but nowhere of any practical value, because of their highly siliceous character. The slates associated with these iron deposits are commonly highly argillaceous as well as siliceous, as is indicated by their color, texture and strong clayey odor. Similar ferruginous slates occur also on the head waters of Rapid creek a short distance north of the Elkhorn prairie.*

* Report on the Geology and Resources of the Black Hills of Dakota, 1880, pp 57-58.

Since Newton's work in the Hills certain deposits have been found near the Box Elder that are claimed to be fairly free from silica and suitable for the production of iron.

Ten miles west-northwest of Rapid City, near Hat mound, a body of compact red hematite has been exposed. A partial analysis of this ore gave Fe_2O_3 , 82.05 per cent and SiO_2 , 15.49 per cent. The ore occurs in the form of a vein enclosed by slates and quartzites and resembles closely the better grade of Lake Superior hard ores. Two varieties are observed. One is a very dense red ore which breaks with smooth surfaces and with distinct conchoidal fracture. The other has a less pronounced red color, is slightly less compact, and breaks with a more uneven fracture. The exposure is not large, it being confined to a small rocky point near a small stream which runs northward into Bogus Jim creek about one mile above the point where the latter joins Box Elder creek.

Another property that has attracted considerable attention is Iron mountain, situated on the Pennington-Custer county line four miles south of Keystone, the nearest railway station. The writer has not had opportunity to see this interesting deposit, but the following description has been obtained from Mr. Samuel Scott, of Custer. The ore is in close association with granite, slate and quartzite. The course of the vein is nearly northwest-southeast and can be traced for several miles. The ore which seems to be of value extends through a length of less than one mile. On the county line the width of the vein is seven hundred feet, but much of this is not good ore. A short distance south of the line it reaches its greatest width—nine hundred fifty feet. The material is hematite, limonite, "jasper ore" and red ochre. The following analyses of the hematite ore and the jasper ore were furnished by Mr. Scott, the exact chemical formulas not being indicated:

	Hematite Ore.	Jasper Ore.
Iron.....	55.40	60.43
Silica.....	7.41	6.24
Phosphorus.....	.88	.34
Manganese.....	1.97	2.56
Aluminium.....	1.46	.36
Lime.....	1.21	.95
Copper.....	.41	.10
Magnesium.....	.47	.35
Organic and volatile matter	3.12	2.07
Moisture.....	9.60	10.06

The ore contains also gold and silver. A series of three hundred assays gave an average of \$3.10 in gold and one-half ounce of silver per ton.

It has been suggested that the iron may represent the gossan of a copper ledge. Much of the ore resembles gossan, and considerable indications of copper have been found in the immediate vicinity, but exploratory work has not progressed sufficiently to give more than a conjecture on this point.

So far as has been learned, with the exception of the shipment from Nahant already mentioned, little or no iron ore has been sent out of the Hills. Occasionally there is a demand for ochre, and recently thirty car loads of such material, obtained near Rochford, were ground at the Mineral Paint Works at Custer and sent to Aurora, Illinois, there to be mixed with oil and prepared for market.

MANGANESE.

Manganese minerals are found widely distributed through the Hills. A few deposits have attracted special attention, and effort has been made to prove their economic value. The chief occurrences are in the Algonkian in Pennington and Custer counties; in the lowest thin beds of the Carboniferous near Redfern, and in the Minnelusa sandstone near Argyle. Careful analyses of samples are not available, and little can be given by way of description of the deposits. The most extensive exposure seems to be at Argyle. The manganese minerals, chiefly pyrolusite, are disseminated through a thirty-five-foot sandstone stratum which is

well exposed in a cut at this place made by a tributary of Red Canyon creek, the minerals being in places concentrated into compact layers or bunches several feet in thickness. Light shipments have been made from one or two localities, but it seems that none of the material has fully met the requirements, and, so far as can be learned, little development work is now being done.

SILVER AND LEAD.

With the exception of the small but fairly regular amount of silver obtained from gold bullion, silver is closely associated in the Black Hills with lead. Argentiferous galena ores are found in the Galena district southeast of Deadwood, in the Carbonate district northwest of Deadwood, and at Spokane, five miles southeast of Keystone. Galena is occasionally found elsewhere, particularly in the vicinity of Hayward and of Silver City, but apparently little or no contribution to the output of the galena ores has been made from other localities than the three mentioned. Cerargyrite, silver chloride, is abundant at Carbonate, particularly in the Iron Hill mine. It is also found in the Trojan and other mines near Portland. Cerussite, lead carbonate, occurs in quantity both at Carbonate and at Galena.

The earliest developments worthy of note were made at Galena, where in 1881 a smelter and a chloridizing plant were erected. These were in operation more or less continuously until 1891, the chief production being during the years 1881-84.

In 1886 silver-lead ores were found near Carbonate, the discovery of lead-carbonate on the West Virginia claim giving the camp its name. Large bodies of rich cerargyrite, galena and cerussite ores were disclosed in the Iron Hill mine, and for two years or more this mine was the dominating factor in the Black Hills silver production. A smelter and a chloridizing plant were erected, but after a run of about two years they closed down and all operations ceased. During the period of activity much good ore escaped over the dump, and effort is being made at the present time to recover this material.

The Spokane mine produced considerable lead and silver during the years 1898-1900. The mine is now idle.

The character of the ore bodies in the various localities differs widely. They occur in the Algonkian in veins, in the Cambrian as shoots, and in the Carboniferous as contact deposits, the latter two graduating more or less into each other.

The ores at Spokane, at Silver City and near Hayward are in fairly well-defined quartz veins in the schists and slates. Most of the galena is well crystallized, although at Silver City a cryptocrystalline variety is found. At the latter place antimony is not an uncommon associate, the mineral jamesonite, $2PbS, Sb_2S_3$ occurring in some deposits.

At the Iron Hill mine the ore bodies occupy a nearly vertical position along a porphyry dike where it cuts through the massive limestone. Only the briefest descriptions of this mine are found in the literature, and as it is now nearly filled with water, few details can be given. Well defined faulting is said to have been observed, and this has apparently taken place subsequent to the deposition of the ore. The ore, which has a peculiar jaspery appearance, due to the large amount of limonite present, is locally known as "liver colored rock." The jaspery nature of the ore is not distinctive, however, since much of the comparatively barren rock presents a similar appearance. Occasionally the ore is distinctly granular and retains apparently more of the original nature of the limestone of which the ore is an impregnation.

The deposits in the vicinity of Galena are within the Cambrian and are found both upon the lower quartzite and in the higher shales. The lower contact ores consist of hematite and carbonate of iron, together with small quantities of lead and galena carrying gold and silver, the gold predominating where the ores carry any considerable value. The ores in the higher shales are found in various horizons. These have been the chief source of the ore in the district. Like the ores of the lower contact, they consist of iron oxides with some carbonates of iron and lead, but in places where the best ore bodies have been discovered large

amounts of galena have occurred. Unlike the lower contact deposits, these ores contain nearly their entire value of precious metals in silver, there being rarely more than mere traces of gold.* These ores, like the Iron Hill carboniferous ores, are impregnations due to secretions from water which has gained access to the easily replaceable calcareous materials through numerous vertical cracks or fissures produced by the intrusion of the post-Cretaceous igneous rocks, their origin being similar to that of the siliceous gold ores described elsewhere in this paper.

Almost no definite statistics are at hand concerning the output of lead from the Hills. The following table in round numbers of the annual output of silver follows fairly closely the statistics as given by the Mineral Industry and by the Director of the Mint. The figures are evidently defective in detail, particularly in the early eighties, but the table as a whole is believed to be as nearly correct as it is possible to make it with the data at hand:

Annual Silver Output of the Black Hills.

Year.	Output.	Year.	Output.	Year.	Output.
1875		1884	\$150,000	1893	\$182,000
1876		1885	100,000	1894	106,000
1877		1886	425,000	1895	206,000
1878		1887	540,000	1896	302,000
1879	\$ 10,000	1888	100,000	1897	299,000
1880	71,000	1889	135,000	1898	197,000
1881	70,000	1890	129,000	1899	209,000
1882	175,000	1891	129,000	1900	129,000
1883	150,000	1892	100,000	1901	140,000
Total					\$4,154,000

TIN.

Cassiterite was first identified in the Black Hills in 1876 by Mr. Richard Pearce, of Denver, Colorado, who detected it as stream tin in gold dust from the northern Hills. The second discovery was made on Elk gulch in the southern Hills in April, 1877. The material from the latter place was assayed by Theodore Vosburg, but the true na-

* Barrell, R. W. Bear Butte Mineral Formation, Black Hills Mining Review, June 18, 1900, p. 7.

ture of the bullion was first recognized by Mr. Fred J. Cross.*

These discoveries seem not to have aroused any special interest, and it was not until 1883 that the mineral attracted particular attention. In June of that year Major A. J. Simons, of Rapid City, sent to General Gashwiler, of San Francisco, specimens of a heavy dark colored mineral from the Etta mine (plate 18), which upon examination proved to be cassiterite of excellent quality.† At the time of the discovery of the cassiterite the Etta was being exploited for mica, but this work quickly ceased and the property in 1884 coming into the possession of the Harney Peak Tin Mining, Milling and Manufacturing company, became one of the chief centers of interest in the search for tin ore. During this period of activity in prospecting, a vast sum of money was spent by various companies, chief among which was the Harney Peak company already mentioned. Hundreds of mining claims were purchased, considerable exploratory work was done, and several mills were erected. A few thousand pounds of metallic tin were produced, but desired results failed to appear, litigation ensued and operations ceased. Various causes have been assigned for the failure to realize better returns for the vast amount of money spent, many mining men contending that the tin is present in places in sufficient quantity to be worked with profit. The deposits possess much of scientific interest, and in view of their possible future value the following brief description is given.

The cassiterite is found in place and as stream tin in two districts, namely, the Harney Peak district in Pennington and Custer counties, and in the Nigger Hill district in the northwestern part of the Hills near the Wyoming-South Dakota line. The rock containing cassiterite in place is an extremely coarse granite known as pegmatite, the pegmatite occurring in the form of dikes. These dikes cut the country rock in every direction, although generally in accurate or approximate conformity with the schistosity when

* Headden, William P. Notes on the Discovery and Occurrence of Tin Ore in the Black Hills, S. D. Col. Sci. Soc., Vol. III, pt. III, pp. 347-350.

† Blake, W. P. Tin. Min. Res. of the United States, 1883-84, U. S. G. S., p. 602.

occurring in metamorphic rocks. They range in size up to many yards in width and hundreds of yards in length. When cutting through the country granite the dikes generally show a depression, due to the more rapid weathering of the pegmatite, but in areas of schistose rocks its relative rate of weathering is usually slower than the enclosing rocks, hence it is often seen in such places as a projecting mass, which not infrequently can be traced for considerable distances by the topography alone.

The tin occurs almost alone in the form of cassiterite, SnO_2 . Cupro-cassiterite occurs at the Etta, stannite has been identified, and a peculiar hydrous oxide is occasionally found, but aside from their scientific interest are of no value. The cassiterite is found as a constituent mineral of the pegmatite in crystals or masses of all sizes up to many pounds weight. Some of the heavier masses at the Etta weighed fifty or sixty pounds, and lumps of three or four pounds were common.* Many claims afford crystals weighing several ounces, and in some localities specimens suitable for gems have been found, but most of the material in all of the mines comes in fine particles. The mineral occurs chiefly in a feldspar-muscovite aggregate, but is occasionally found in a quartz-muscovite aggregate or in quartz alone. The following mineral associates are listed as having been found:

Albite-oligoclase	Graphite	Petalite
Almandite	Grossularite	Quartz
Andalusite	Heterosite	Rutile
Apatite	Ilmenite	Scheelite
Arsenopyrite	Lepidolite	Scorodite
Autunite	Lencopyrite	Sphene
Barite	Liebnerite	Spinel
Beryl	Lollingite	Spodumene
Biotite	Melanite	Stannite
Bismuth	Microcline	Tantalite
Columbite	Molybdenite	Tourmaline
Corundum	Monazite	Triphylite
Cupro-cassiterite	Muscovite	Triplite
Epidote	Olivinite	Wolframite
Galena	Orthoclase	Zircon
Graphite		

* Blake, W. P. Tin. Min. Res. of the United States, 1883-84, U. S. G. S., p. 607.



THE ETTA MINE NEAR KEYSTONE.



THE HIDDEN FORTUNE MINE NEAR LEAD.

A few of these minerals deserve special mention. Spodumene occurs in extremely large crystals, and being of some economic importance on account of its lithia content, receives a more extended notice elsewhere in this paper. The beryl, the tourmaline and the columbite are also noteworthy. Beryls one foot or more in length are not uncommon, and one crystal was found which measured fourteen inches in diameter. Tourmaline is particularly abundant, occurring in well defined crystals and in the massive state, the crystals being sometimes six inches or more in diameter. The columbite is found less widely distributed, but well developed, and in the Bob Ingersoll mine one mass obtained, said to be the largest known to mineralogical science, weighed approximately one ton.* Cupro-cassiterite and the variety of triplite known as griphite are found only in the Black Hills, the first mineral having been described by Mr. Titus Ulke† and the second by Prof. W. P. Head- den.‡

The cassiterite runs high in metallic tin, as indicated by the following analyses: §

	Stannic Oxide. Per Cent.	Metallic Tin. Per Cent.
Occidental mine	96.42	75.86
Tin Mountain mine	97.5	76.7
First Find mine.....	94.7	74.5
Nigger Hill stream tin ..	92.6	72.84
Nigger Hill stream tin ..	93.	73.21
Southern Hills stream tin	92.8	73.

Professor Carpenter calls attention to the fact that while the stream tin is clearly derived from the tin veins by disintegration, yet the vein tin carries a higher percentage of the metal than does the stream tin. This is peculiar, as alluvial tin is generally purer than lode tin, because during the process of disintegration and transportation the

* Blake, William P. Columbite in the Black Hills of Dakota, *Am. Jour. Sci.*, 3d Ser. Vol. XXVIII, pp. 340-341.

† Ulke, Titus. A New Tin Mineral in the Black Hills, *Am. Inst. Min. Eng., Trans.*, Vol. XXI, pp. 240-241.

‡ Headden, William P. A New Phosphate from the Black Hills of South Dakota, *Am. Jour. Sci.*, 3d Ser., Vol. XLI, pp. 415-417.

§ Carpenter, Franklin R. The Mineral Resources of the Black Hills, Their Character, Occurrence and Extent, *Dak. Sch. Mines, Prelim. Rept.*, 1888, pp. 141-142.

more soluble impurities are removed. Heavy minerals other than cassiterite, such as columbite, tantalite, etc., are found in the stream gravels of the Black Hills and possibly these aid in lowering the percentage of tin.

The analyses given indicate the excellent character of the cassiterite, and no one acquainted with the tin deposits can doubt their great extent, hence the chief uncertainty is whether or not the mineral occurs sufficiently concentrated in any of the deposits to yield a continuous supply of ore of high enough grade to be profitably worked. High grade samples can be readily obtained from many localities, but percentages in such cases have little value from an economic standpoint. Of the various reports and assays that have been made on the tin properties the following estimates and results will best serve our purpose:*

Results of Assays of Harney Peak Tin Ores.

Name of Assayer.	Average No. pounds black tin per long ton of 2240 pounds rock.	Pounds of white metal yield per ton of 2240 lbs.	Percentage of tin.
Prof. W. P. Blake	72.8	36.4	1.625
E. N. Riotte	67.2		
Prof. H. O. Hoffman	57.54	39.2	1.746
Prof. C. M. Vincent (estimate).....	30.	22.5	1.
Prof. C. M. Vincent (sel. samples)..		38.8	1.732
Capt. Josiah Thomas (estimate)...	40.	29.2	1.3

Prof. Carpenter estimates that in sorting the ore, if only such rock is saved as will carry ten pounds or more of cassiterite to the ton, the average for the Black Hills tin ores will probably reach two per cent. Many individuals consider this estimate too high, while others think it too low.

During the year 1892 five thousand tons of ore were milled by the Harney Peak company, but the concentrates collected were estimated to yield only one-fourth of one per cent of metallic tin per ton of rock crushed. Loss in concentration incidental to the use of new machinery doubt-

* Rolker, Charles M. The Production of Tin in Various Parts of the World, 16th Ann. Rep., U. S. G. S., Min. Res., Pt. III, p. 533.

less influenced the result, but it is claimed that the loss was much greater than it should have been. The ore for this run, which occupied about two months, was obtained from many claims, and apparently little or no account was kept of the relative value of the ores from the various places.

In the minds of many mining men the failure to profitably work the tin deposits in the past was due in great part to unwise management and not to the low grade of the ore. In view of this belief some effort is now being made to reopen old mines, and possibly by careful avoidance of extravagant methods some of the more favorable deposits may yet be made to yield fair returns.

The total amount of metallic tin that has been produced from Black Hills ores is indefinite but small. In 1884 several hundred pounds were produced, in 1891 four hundred forty-seven pounds, and in 1893 nearly nine thousand pounds. Previous to this time ore and concentrates, including stream tin, the latter chiefly from the Nigger Hill district, were shipped to England, sufficient to produce perhaps two or three tons of metal. Considerable stream tin has been shipped to England from the Nigger Hill district during the past few years, so that the total product of metallic tin from the Black Hills has possibly reached 50,000 pounds. At the present time the placer miners of the Nigger Hill district have a number of tons of stream tin in their possession, and Mr. M. R. Hydliff, of Bear gulch, has more than one hundred pounds of the metal which he has obtained from stream tin by such simple means as the assayer with small laboratory is able to utilize. One specimen of nearly pure stream tin (cassiterite) found by Mr. Hydliff in Bear gulch and now in his possession, weighs eighty ounces.

TUNGSTEN.

Tungsten of commercial importance was discovered near Lead in 1899.

In the early days of the tin excitement in the Black Hills wolframite, FeW_2O_6 , was identified at various localities in the Harney Peak and Nigger Hill granite districts, but

the deposits were not considered important and no effort was made to prospect for the mineral. Since the discovery of the deposits in the northern Hills, special search has been made for commercially valuable deposits in the granite areas, but, with the possible exception of one or two properties in the Harney peak region, the search thus far has been fruitless.

The existence in the refractory siliceous gold ores near Lead and on Yellow creek of a heavy mineral locally called "black iron" was known for several years prior to 1899. This black material when sufficiently auriferous to be of value as a gold ore was sent to the smelter and treated for its gold content. When low in gold values, which was frequently the case, it was thrown out as worthless material, and thus considerable quantities gradually accumulated in the waste heaps of the mines where it occurs.

Mr. O. A. Reitz, a teacher in the Lead high school, became interested in the mineral on account of its high specific gravity, and in January, 1899, secured some of the material for examination. A few simple tests proved the mineral to be wolframite. Manufacturers of tungsten steel immediately became interested in the region and various small sales of ore were quickly made at prices ranging from \$100 to \$250 a ton, the percentage of tungstic acid in these shipments varying from 35 to 54 per cent.

Only two localities have thus far afforded ore in any appreciable quantity. One lies just north of Lead. The other is situated about two and one-half miles south-south-east of Lead. The deposits in both localities are intimately associated with the Cambrian siliceous ores. Much of the hill to the north of Lead, forming the divide between Gold Run and Deadwood gulches, is capped by Cambrian rocks, and it is near the gently rolling crest of the western portion of this hill that the most extensive wolframite deposits have been found. These are known as the Lead deposits, and the following properties have contributed to the output: Durango, Harrison, Sula, Hidden Fortune (plate 19), Reddy and Golden Crown. South-southeast of Lead on the ridge between Yellow and Whitewood creeks there is

a northerly projecting tongue of Cambrian rocks in which wolframite occurs in considerable abundance, and the deposits here are known as the Yellow creek deposits. The Wasp No. 2 and the Two Strike mines have been the chief producers. A straight line drawn through the two wolframite areas follows closely the schistosity of the upturned metamorphic rocks below, and the open cuts of the Homestake mine, which are situated immediately east of the Lead deposits, lie in a line nearly parallel to that connecting the wolframite areas.

The wolframite bodies are quite irregular in shape, although partaking to some extent of the form or outline of the flat gold ore shoots with which they occur. Their thickness is rarely more than two feet, and the concentrated portions are generally only a few inches thick. Their lateral extent occasionally reaches thirty feet or more. Irving calls attention to the fact that the wolframite should be considered in the nature of a basic phase of the siliceous gold ores rather than as a separate and distinct deposit, since it always occurs in intimate association with them.*

The wolframite is dense, black, granular, and shows good crystal faces only when the mineral has formed on the surface of cavities. Crystal druses of yellowish and green scheelite, CaWO_4 , are common. Barite, BaSO_4 , is frequently present, sometimes in great abundance in large white tabular crystals. Stibnite, Sb_2S_3 , in long slender crystals has been found in the leaner ores of Yellow creek.

The last two minerals have been found, however, in siliceous gold ores elsewhere where no wolframite has been detected, hence possibly have little or no direct connection with the deposition of the wolframite. The wolframite from the Harney Peak and Nigger Hill districts is distinctly crystalline and is easily distinguished from the ore of Lead and Yellow creek. It occurs in pegmatitic granite in close association with quartz. The mineral is unevenly distributed throughout the pegmatite and occurs in bunches or masses sometimes of several pounds weight. The per-

* Irving, J. D. Some Recently Exploited Deposits of Wolframite in the Black Hills of South Dakota, A. I. M. E. Trans., Pamphlet Edition, February, 1901.

centage of tungstic trioxide is high, as is also manganese oxide, the former being given as 74.82 per cent and the latter at 19.95 per cent.

The following analysis of Yellow creek wolframite is by Mr. W. F. Hillebrand, of the United States Geological Survey.* The specimens for analysis were obtained at the Two Strike mine:

SiO ₂	12.87
WO ₃	61.50
Fe ₂ O ₃	3.85
FeO	9.18
Al ₂ O ₃	0.52
MnO	8.21
CaO	0.93
SrO	0.02
BaO	0.04
K ₂ O + Na ₂ O + Li ₂ O	0.08
H ₂ O †	0.20
H ₂ O ‡	0.87
As ₂ O ₅	1.25
P ₂ O ₅	0.12
V ₂ O ₅	Trace
S or SO ₃	Trace
	99.64

Assays:—Gold, 0.05 ounces per ton; silver, 0.25 ounces per ton.

Extremely minute traces of magnesia, zinc, copper, antimony and tin were also found.

Concerning the mode of formation of the deposits and the probable source of material, I quote at length from Mr. Irving:

That they are formed through the gradual replacement of the country rock by wolframite, seems to the writer to be clearly indicated by the character of the ore, the nature of the beds in which it is found, and the metasomatic origin of the ores with which it is inseparably connected. First, the wolframite itself is filled with cavities of irregular form and distribution, such as are almost always to be observed in ores formed by replacement, where the aggregate

* Irving, J. D. Some Recently Exploited Deposits of Wolframite in the Black Hills of South Dakota, A. I. M. E. Trans., Pamphlet Edition, February, 1901.

† Up to 195° C.

‡ Above 105° C.

volume of the mineral introduced is smaller than that of the original rock; secondly, the beds in which the ore occurs, are composed chiefly of magnesian limestone, often quite impure, it is true, but of a pre-vaillingly soluble character; thirdly, the wolframite is an integral part of the shoots of siliceous gold ore, the metasomatic origin of which has been conclusively proved by careful microscopic study.

As regards the source from which the tungsten minerals have been derived, no positive conclusion can be formed; but the relation of the deposits to the geology and to the other ore bodies of the neighborhood seems to furnish some evidence as to their derivation. They are found at two rather widely separated localities on the west side of the outcrop of the Homestake ore body. Along this line there has taken place, first, the heavy mineralization of the Algonkian rocks, which has produced that well-known ore body; secondly, the mineralization of the Cambrian above, resulting in the formation of siliceous gold ores, which are richer and contain a more varied assortment of secondary minerals than ores of similar character away from the Homestake lode; and, thirdly, the formation of the wolframite ores themselves. It seems, then, that the line of strike of the Homestake lode is also a line along which mineralization has been both varied and unusually intense. During this extensive mineralization, the circulation of waters capable of dissolving the metallic contents of the surrounding rocks, must have been active. That these waters were, in the case of the siliceous ores, and hence in the case of the wolframite, ascending waters, is proved by the concentration of these deposits beneath impervious beds. It is therefore not unreasonable to suppose that if wolframite occurred in the Algonkian rocks at some point below the deposits now worked, just as it occurs in its normal relations at other points within the Hills, the action of ascending thermal waters upon this material should have given rise to the mineral-bearing solutions which carried the wolframite up to its present position, and, there encountering rock sufficiently soluble to admit of metasomatic interchange, should have redeposited their metallic contents.

If this be true, it may be said that there are two distinct but genetically related types of wolframite deposit in this region: (1) That which characteristically occurs in the granitic and related rocks of the Algonkian, and is comparable with the greater number of such deposits from other parts of the world. This is instanced by the wolframite from Nigger Hill and the Etta tin mines in the southern Black Hills. It may be termed a "primary" deposit. (2) That which has been formed by the solution of bodies of the first type, and a metasomatic redeposition of the material in stratigraphically higher beds. This may be termed "secondary."*

* Irving, J. D. Some Recently Exploited Deposits of Wolframite in the Black Hills of South Dakota, A. I. M. E. Trans., Pamphlet Edition, February, 1901.

The ore is low grade, demanding hand picking or machine concentration. Most of the material sold has been concentrated sufficiently to give from 38 per cent to 50 per cent tungstic acid. Of the producing mines the Durango has placed the largest amount upon the market, while the Harrison has at the present time the largest amount immediately available. The price has varied from less than \$100 to more than \$200 a ton, the earlier shipments commanding the higher prices. The total amount marketed will approximate 140 tons. Practically all of this was sold during the years 1899 and 1900.

GRAPHITE.

Graphitic slates are abundant in many parts of the Hills and in not a few places the percentage of graphite is sufficiently high to arouse some interest in the economic possibilities of the deposits. Considerable prospecting has been done in the central Hills, particularly near Custer and Rochford. Recently sixteen car loads of the mineral were ground at the Mineral Paint works in Custer and shipped to Aurora, Illinois, for final preparation for market.

MICA.

The earliest explorations for mica in the Black Hills were made in 1879, the McMacken mine (plate 20) near Custer being the first property upon which much work was done. Up to July 1, 1884, it had produced 45,000 pounds of cut mica, at an average price of \$3 a pound, or a total of \$135,000. The New York, the Lost Bonanza and the Climax mines were opened only a little later, and up to July 1, 1884, had produced as follows: New York, 5,700 pounds, value \$19,950; Lost Bonanza, 26,000 pounds, value \$113,100; Climax, 7940 pounds, value \$34,539. In addition to these mines, other smaller mines produced 40,000 pounds, value \$140,000. The total product for the year 1884 amounted to 18,150 pounds, worth \$63,525. The mines which contributed to this output were the Cli-

max, the Lost Bonanza, the White Spar, the Eureka, the New York, the Last Chance, the Warren, the Keystone, the Window Light, the Millard and the Nellie, of Custer county. In addition to these a small group of mines near Keystone, in Pennington county, including the Emma, the Peerless, the Celia and the Alice, produced some mica, the amount not known.*

With the output of 1884, most of the mines practically ceased operating, the work during subsequent years until 1899 consisting of scarcely more than such development work as is necessary to hold claims. During this period of quiescence the output so far as I am able to learn was as follows: In 1886, six hundred pounds; 1896, eight thousand one hundred pounds; 1898, nine hundred ninety pounds. In 1899 and 1900 the output greatly increased. During the latter year scrap mica was shipped for the first time, all of the earlier product having been sold in the form of sheets. The output in 1899 was 20,299 pounds, valued at \$18,000. In 1900 the sheet mica output reached the unprecedented amount of 65,000 pounds, value \$45,000, while the production of scrap mica amounted to 222 tons, worth \$1,554. The New York, the Lost Bonanza and the Monarch mines were the chief producers, most of the output going to the Chicago and the New York markets. During 1901 approximately 200,000 pounds were shipped, but the proportion of sheet and scrap was not learned. The entire production came from the Crown (McMackin) mine and the New York mine.

The mica is found in pegmatite dikes, which occur in great abundance in the granite region of Pennington and Custer counties. The dike material is made up chiefly of coarsely crystalline quartz, feldspar and mica, the masses of quartz and feldspar being not infrequently developed in pieces of many pounds weight, and mica books two feet or more in diameter are said to have been mined. For a fuller description of these dikes the reader is referred to the tin deposits described elsewhere in this paper.

Many of the dikes do not contain large mica books in

* Clarke, F. W. Mica. Min. Res. of the United States, 1883-84, U. S. G. S., pp. 909-910.

sufficient amount to make them profitable producers, but all have the mica present to a greater or less extent. The books sometimes show much regularity of arrangement with reference to the hanging wall and the foot wall, the books being situated near the wall and oriented in all planes perpendicular to it. This arrangement is particularly noticeable in the New York mine, five miles west of Custer, where the pegmatite dike has a thickness of forty feet, and in which most of the workable mica lies within a few feet of the outer walls, the side next the foot wall having produced the larger quantity. In many mines the mica is irregularly distributed within the dike, and when such is the case much worthless gangue must be removed, and exploratory work is necessarily carried on with some degree of uncertainty. Thus it is clear that the percentage of mica in given portions of the dike varies widely. The mica occasionally amounts to eight or ten per cent of the total mass of pegmatite mined, but it is generally much less.

In the early days, when mining was active, stove mica was the chief product, but now most of the material is sold for use in electrical work. Much of the scrap mica formerly considered as waste material has been sold to be ground for lubricating purposes.

Concerning the probable future development of the Black Hills mica industry I cannot do better than to quote from Professor J. A. Holmes, who has made a study of the deposits:

There are undoubtedly large quantities of mica which, with fair prices and modern mining methods, can be profitably taken from the McMackin, Climax, New York, Lost Bonanza, White Star and a dozen other mines in that district. Besides these there are numerous other large unopened dikes which exhibit on the surface as good prospects as did originally many of those which have been more or less developed. The mica in this district is, as a rule, good in color and free from iron specks. Its greatest defect is the considerable extent to which the blocks or "books" of mica are ruled and wedge-shaped, making the sheets smaller and the splitting defective. But, notwithstanding these defects, there are still to be found in Custer and Pennington counties large quantities of high grade mica. Indeed it may be fairly claimed that mica mining in the Black Hills region is yet in its infancy.*

* Holmes, J. A. Mica Deposits of the United States. Mineral Resources of the United States, 1898, U. S. G. S., Part VI. cont., pp. 705-706.

SPODUMENE.

Spodumene, $\text{LiAl}(\text{SiO}_3)_2$, has recently achieved commercial importance in the Black Hills, and considerable local activity has been shown in the development of the industry. The deposits are all found in the Harney Peak district in Custer and Pennington counties.

Attention was first attracted to the mineral during the tin mining activity, at which time its occurrence was observed in several localities. The most noted of these is the Etta mine (plate 18), at which place exposures have been made of some of the largest crystals known to this mineral species. Owing to their extreme size and irregularity of position, mining operations seldom disclose complete lengths, but Professor Blake mentions one showing in the sides of a drift for thirty-six feet without break or deflection.* In diameter they range up to four feet or more. Crystals three feet in diameter are not uncommon, and those having diameter of as much as two feet are abundant. Mr. Samuel Scott informs me of one crystal on property adjoining the townsite of Custer that has been exposed for a distance of ten feet, which measures in cross section five feet four inches by four feet nine inches.

The crystals or "logs," as they are more generally called by the local miners, lie imbedded in the pegmatite matrix already referred to under the subject of tin, and are intimately associated with the tin-bearing material. They apparently lie in all possible positions with reference to each other, sometimes considerably separated, sometimes segregated in bunches, but more often evenly distributed through the pegmatite in great profusion (plate 21).

The mineral associates of the spodumene in the Black Hills are practically the same as those given elsewhere in this paper for cassiterite, and, with the possible exception of two or three unimportant minerals there mentioned, were contemporaneous. In reference to their origin Prof. Blake says:

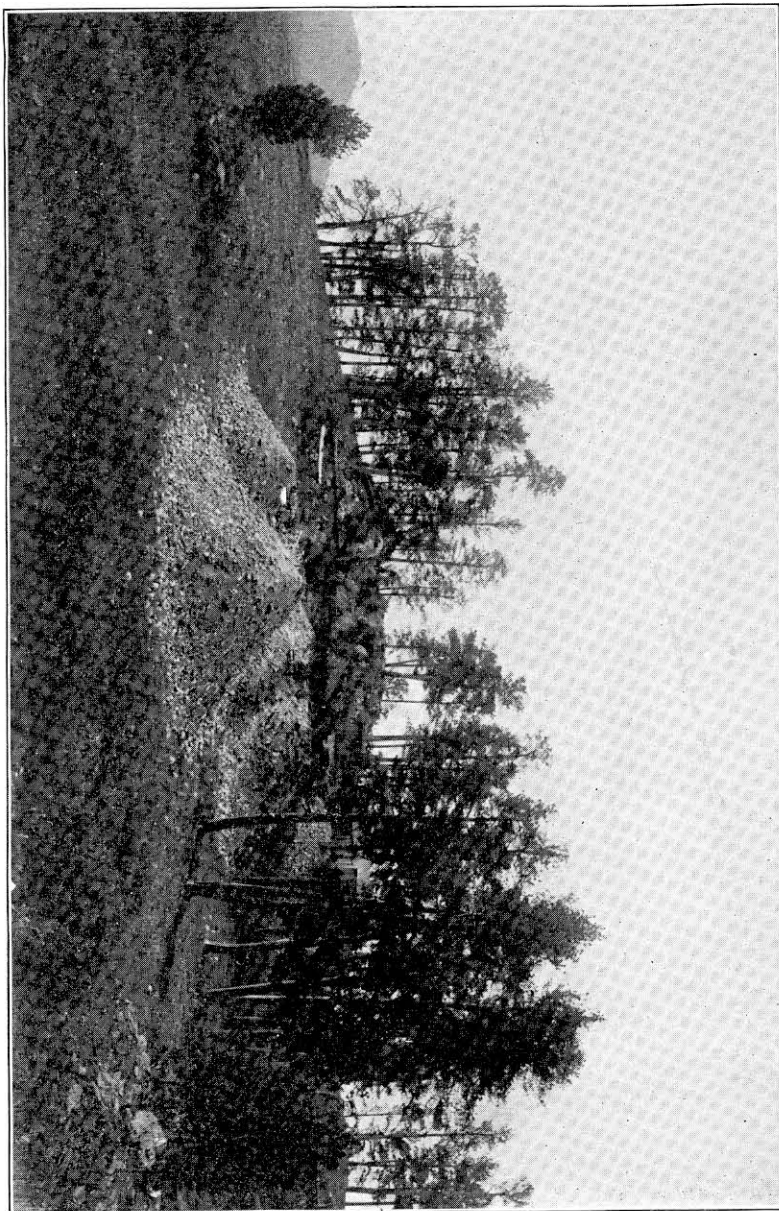
* Blake, W. P. Tin. Min. Res. of the United States, 1883-84, U. S. G. S., p. 608.

All these minerals appear to have crystallized out of a semifluid or pasty magma in which the elements were free to arrange themselves from one side of the dike to the other, and to separate out by slow crystallization. There is a banded arrangement, sometimes very distinct and again obscure; but different from the banded structure seen in fissure veins, where there appears to have been an open fissure subsequently filled gradually by the flow of water depositing layer after layer upon each side of the fissure until it became filled. In the dikes the rude structure seems rather to be due to the crystallization of the magma which filled the space between the walls, the difference of the structure of the portion next to the walls being the result possibly of difference of pressure or temperature, or the different temperature or conditions governing the formation of one compound after another. Thus in the great dike or injected mass of the Etta mine, mica is generally found next to the walls, so also at the Ingersoll, while feldspar and quartz fill the center; but this central mass is penetrated in every direction by the enormous crystals of spodumene, the cassiterite being disseminated in bunches, but particularly in the included masses of albitic greisen which seem to have filled the spaces left after the other minerals had assumed their form.*

Attention seems to have been first directed in 1895 to the possible economic value of the spodumene. During the summer of that year a lithium analysis of the mineral was made at the South Dakota School of Mines, and Dr. McGillicuddy, then Dean of the School, endeavored to have the mineral investigated by reliable chemical manufacturers. Little or no active attention was given to the subject until three years later, when, during the latter part of 1898, one carload of thirty tons of the spodumene was mined at the Etta for experimental purposes, under the direction of Messrs. Reimbold and Company, of Omaha. During the following year, 1899, the Etta produced 500 tons, and in 1900 approximately 700 tons. A considerable proportion, however, of the latter amount remained last year at the mine ready for shipment, and active operations for the time being have ceased.

Subsequent to the earlier shipments from the Etta other properties were developed and various amounts have been mined. Several of these properties show large crystals, especially the Wood mine, two and one-half miles east of

*Blake, W. P. Tin. Min. Res. of the United States, 1883-84, U. S. G. S., pp. 596-597.



THE MACMACKIN MICA MINE NEAR CUSTER.



SPODUMENE CRYSTALS, ETTA MINE, NEAR KEYSTONE.

Keystone; the Boomerang one mile southeast of Keystone; the Sunday Fraction, immediately adjoining the Boomerang; and the Palmer Gulch, five miles southeast of Hill City. Each of these has produced about 200 tons. In addition to these properties spodumene has been found on the Grand View claims, situated adjoining the Boomerang and the Sunday Fraction; on the Tin Mountain vein, six miles west of Custer; on the veins of the Telegraph Group; and on properties near Custer and Glendale. It is doubtless present also in greater or less abundance on many claims where little attention has been paid to its observation.

The value of the mineral varies with the lithia content. The samples analyzed at the School of Mines carried 6.16 per cent lithia, and this is perhaps a fair average. The chief use of the product is in the manufacture of lithium salts, chiefly lithium carbonate, for the preparation of lithia water. Most lithium salts are obtained from lepidolite, nearly all of the supply for the United States being imported from Europe. The chemical processes are complex and rather carefully guarded, and it has been found difficult to develop methods for extracting the lithia content from the spodumene with profit. For this reason there has been practically no regular price offered for the mineral, most of the material having been secured by direct purchase of claims or by royalty arrangement. The total cost per ton of most of the material delivered on the car at Keystone has been between \$20 and \$25. A total amount of about 1600 tons has been shipped.

MISCELLANEOUS MINERALS.

Of the many minerals occurring within the Hills, a few in addition to those already described deserve mention here.

Antimony in the form of jamesonite is found in some quantity near Silver City and Rochford. The extent and value of the deposits have not been determined.

Bismuth is occasionally found in the southern Hills, and a few years ago some exploratory work was done in this

connection near Hayward. The efforts failed to reveal good material in quantity, and after a short time operations ceased.

In the early days of Black Hills mining not a little interest was taken in the occurrence of cinnabar on Victoria creek a few miles above Rapid City. Later the mineral was found also near Pactola and Rochford. Considerable prospecting was done but no deposits of importance were found and the search was abandoned.

Nickel is said to occur in many places. Pyrrhotite is found throughout the Algonkian area, and Professor Carpenter states that in practically every instance the pyrrhotite carries nickel. More recent investigation has thrown doubt upon the general application of this statement, and in the absence of careful analyses little can be said in regard to the possibilities of the metal within the Hills.

Uranium minerals have been observed in various places, particularly in the Poisoned Ox mine near Pactola and in the Davier mine on Anna creek near Portland. Uranium is also reported as occurring near Carbonate. At the Poisoned Ox mine the mineral occurs with copper in slates. In the Anna Creek property it is intimately associated with porphyry. At the latter place effort has been made to obtain the mineral in commercial quantities, but as yet success has not been attained.

Rarer minerals of beauty and interest, but of little or no value in metallurgical processes, occur throughout the Hills. To local dealers they are a constant source of profit, but their description does not come within the purpose of this paper.

Resume of Mineral Production.

In the table given below the writer has endeavored to summarize as carefully as possible the total mineral production of the Black Hills. From what has been given on previous pages it may be inferred that the statistics of output of gold, silver, tin, tungsten, mica and spodumene are fairly complete and approximately accurate. The estimate

for lead is quite uncertain and may need correction. The output given for copper, iron, manganese, graphite and miscellaneous minerals is also uncertain. Perhaps least is known of the total production of structural materials, lime for fluxing purposes, abrasive materials, etc., hence the figures given under the head of Structural Materials, etc., should be considered only a rough estimate made with little available data.

Total Mineral Production of the Black Hills, 1875-1901.

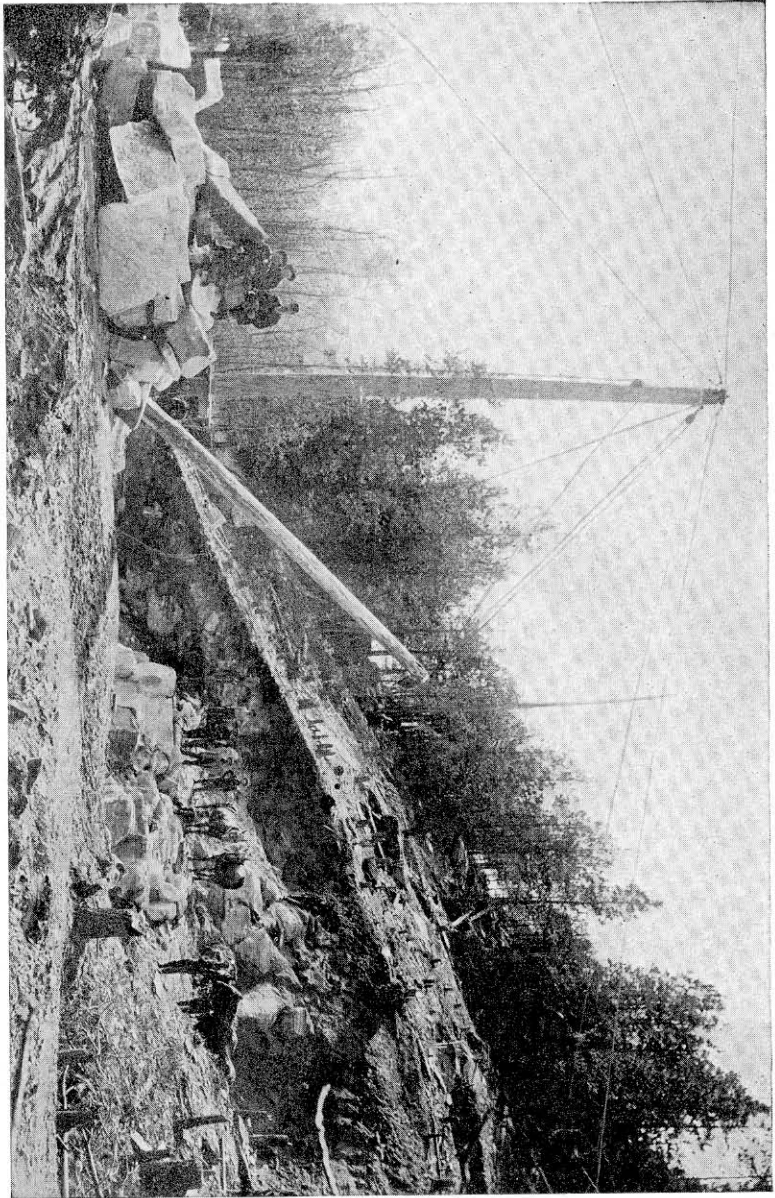
Gold	\$100,210,000
Silver	4,154,000
Lead,	400,000
Copper, Iron, Manganese, Graphite, etc.	40,000
Tin	10,000
Tungsten	25,000
Mica	600,000
Spodumene	40,000
Structural Materials, etc.	3,600,000
Total	\$109,079,000

Conclusion.

The mining interests of the Black Hills were never in a more satisfactory condition than at the present time. For several years the mineral output has been steadily and rapidly increasing. The mining problems have always been fairly simple, and metallurgical difficulties which long hindered the development of much good property have been largely overcome.

The Homestake, the great mine of the Hills, has never before dropped so many stamps nor produced so much gold. Among the siliceous deposits high grade ores continue to be found, nearly all of the developed mines are regularly producing, and at no previous time has it been possible to utilize so much of the low-grade ores. Mines are being profitably opened on mineral deposits which hitherto have received little or no attention, and older mines once abandoned are being rejuvenated. Mills and metal-

lurgical plants judiciously constructed and backed by worthy quantities of suitable ore, are rapidly multiplying, and wise management and modern methods prevail. Good yellow pine, *pinus ponderosa*, suitable for mine timbers, buildings and fuel, is in great abundance, various coal deposits are convenient, and water is generally plentiful. Excellent detailed topographical maps prepared by the United States Geological Survey are available, a bullion depository government assay office has been established at Deadwood, the railroads are advancing in harmony with the needs of the region, and all classes of mineral development give assurance of stability and growth.



By Courtesy of the Burlington Railway.

MARBLE QUARRY NORTHEAST OF CUSTER, RECENTLY OPENED.

MINERAL BUILDING MATERIALS, FUELS AND WATERS OF SOUTH DAKOTA.

By James E. Todd.

Introduction.

A brief general statement covering this ground was given in Bulletin No. 1 of this survey eight years ago, but the steady increase in our knowledge, with the greater demand for such resources, have called loudly for a fuller and more reliable statement concerning them.

Prof. O'Harra in the preceding pages has discussed the metalliferous deposits of the Black Hills, which include all of such resources for the State. This fact calls again for a similar treatment of the principal non-metallic minerals to supplement it. These minerals, moreover, while prominent in the Black Hills extend also in good degree to other parts of the State, and hence the expressed scope of our subject. A few less prominent minerals, as lithographic stone, fuller's earth, etc., will be discussed in connection with the more prominent materials with which they are respectively related.

Geological Formations.

In our discussion of the various deposits we must frequently refer to their geological relations. It will be unnecessary, however, to repeat a synopsis of the geological series, which has already been well stated on page 3. That, though referring particularly to the Black Hills, need not be materially changed to apply to the whole State, for the time which it professes to cover; but it omits the crystal-

line rocks, known as the Algonkian, or Huronian, and also the Cenozoic rocks.

The former include the schists, slates and quartzites which form the core of the Black Hills, underlying and antedating the Cambrian rocks of the series referred to, and also the small area of granite near Big Stone lake and the much larger area of Sioux quartzite.

The last is commonly referred to the later Huronian, while Black Hills rocks are counted early Huronian, and the Big Stone granite is supposed to be still earlier and has been considered Laurentian. More recently the term Algonkian has been used by the United States Geological Survey to include all of them, with the possible exception of the Big Stone rock.

All of them are more or less attended with voluminous eruptives, including granite, diabase, amphibolite and porphyries of great variety. The last are confined entirely to the Black Hills.

The Cenozoic rocks include the Oligocene, or White River formation, and the Miocene, or Loup Fork, together called Tertiary, and the Pleistocene or Quaternary. The Tertiary rocks are estimated to attain a maximum thickness of 600 feet. They cover most of the surface south of White river in its easterly course, and west and northwest to the Black Hills; also, many square miles around the Slim Buttes and Short Pine hills in the northwestern corner of the state.

The Pleistocene deposits comprise the thick deposits of boulder clay which cover the State east of the Missouri river, with various river and lacustrine deposits attending it, and also covering more or less the rest of the State.

Building Stone.

As will appear from the following pages, our commonwealth is well supplied with building stone, but it is mainly restricted to the extreme ends of the State. Moreover, the general development of the State has not reached such

a stage as to call for the systematic and continuous working of the strata, which are known to be excellent and readily accessible. Special enterprises have temporarily stimulated quarrying, so that great possibilities have been repeatedly displayed, but demand has not been sufficient to justify careful plans for continuous working in most cases. Expense of transportation has been an important obstacle.

Under the head of Building Stone we have the crystalline and metamorphic rocks: granites, porphyries, quartzites and marbles, and the clastic and sedimentary rocks: limestones, sandstones and gypsum.

GRANITE.

No quarries of true granite have been opened in this State. Near Big Stone lake, in Minnesota, extensive quarries are worked, and polishing works have been erected. The stone has been pronounced equal and even superior to New England granite for ornamental purposes by those acquainted with both. The granite extends across the line at Big Stone City, and there is an outcrop five to eight miles southwest of that place. The rock rises several feet above the general surface, and there is no reason why it should not be quarried, except distance from the railroad.*

The granite of the Black Hills is usually composed of quartz and mica, the latter locally developed into valuable mica veins. Elsewhere its feldspar, albite, which is ordinarily scarcely perceptible, is remarkably developed, as at the Etta mine. Because of its soda ingredient, of the prominence of mica, and perhaps still more because of its coarse grain, it is not a very durable rock, nor well adapted for working. It is an eruptive rock in the Algonkian slates. Because of the easy erosion of the slates, the granite rises as walls, ridges and needles high above the intervening areas.

The so-called "Sioux Falls granite" is a quartzite and will be described under that head. In justification of the

* These facts are kindly furnished me by Supt. M. M. Ramer, of Grant county.

popular term it may be said that it really possesses in high degree the beauty, strength and durable qualities usually associated with the term granite in the commercial world, while it is superior in color and size of blocks to most quartzites.

PORPHYRIES.

Various kinds of eruptive rocks are widely distributed in the northern Hills. None have been quarried, and they have been little studied from an economic standpoint. They may be conveniently grouped under the popular name of porphyry, though they include several varieties of rhyolite, trachyte, andesite, etc. They vary much in color and in fineness of grain. Some are light colored and would furnish durable and cheerful stone for building whenever needed. Others are of dark shades of green with light phenocrysts or embedded crystals and may sometime be desired for monumental or ornamental work. Samples of the former class appear about Terry peak and on Bear creek east of Deadwood, and of the latter east of Tilford. Dr. J. D. Irving has recently published the results of a careful study of many of them.* In this paper description is given of an eruptive rock in Bear gulch west of Spearfish creek. "It is a dense, black rock, carrying no noticeable phenocrysts, and of extremely fine grain." This may eventually be of value to those desiring a fine black rock for ornamental purposes.

QUARTZITES.

Under this head we group compact rocks composed wholly of quartz or silica. They are metamorphosed sandstones in which the grains have grown and interlocked like the constituent grains of granite, or, in other words, the spaces between the original quartz grains have been so perfectly filled with silica that in breaking fractures cut through the original grains and the embedding cement with equal

* A Contribution to the Geology of the Northern Black Hills. N. Y. Acad. Sci., Annals, Vol. XII, 1899, No. 8, pp. 187-340.

ease. In sandstone, on the the contrary, fractures rarely, if ever, traverse the sand grains. This is perhaps the best distinction between the two classes of rocks, which grade into each other insensibly.

Quartzites are known to occur in the early Huronian, in the later Huronian, in the Cambrian and to a very limited extent in the Cretaceous and in two stages of the Miocene.

MINOR DEPOSITS.—The early Huronian quartzites are so interstratified with schists and dip at so high an angle that they are never likely to be quarried to any extent. Those also of the Cambrian, though lying horizontally, are generally so overlaid and so coarse in texture that they are not available for building stone. The Homestake company reports using quartzite, probably from this horizon for building and as flagging. A sample of the relations of this quartzite to the porphyry and slates is shown in Plate 9.

Some strata in the Cretaceous have been locally silicified so that they may be classed as quartzites. One of these is in the upper part of the Lakota, as I am informed by Mr. Darton of the U. S. Geological Survey. Its best known locality is on Lower Johnny creek, two miles west of the railroad. Specimens of it at the Columbian Exposition attracted much attention because of the variety and beauty of the small pebbles largely composing it. When polished it formed a rare ornamental stone. Mr. Darton says that as far as he could ascertain, there are only a few cubic yards available.

Similar silicification with the development of rather attractive purple tints has been noted also near Hot Springs and south of Minnekahta, but irregular development and the difficulty of preparing it forbids any hope that this will ever be of any economic importance.

Of the quartzite in the Miocene, one in the White river resembles buhrstone and has been found in place only in the Cave hills in strata only two or three feet thick.*

Another in the Loup Fork, is a local vitreous hardening of fine granite sandstone, which affords rough but durable

* South Dakota Geological Survey, Bulletin No. 2, p. 51.

building stone. It would scarcely be used where other forms abounded. As it frequently stands without a rival, it may be considerably used in the vicinity of some of the buttes scattered between the Missouri and the Black Hills. It caps also the Bijou Hills and a few other points east of the Missouri.

THE SIOUX QUARTZITE, named from its prominent occurrence along the Big Sioux river, is the only quartzite, therefore, of any great commercial value. It has been long and favorably known as "Sioux Falls granite," or "jasper." This is a very hard, strong and durable stone of light, cheerful color. It is sometimes of a mottled gray color, but usually of different shades of pink, or of light purple. In a few localities, strata several feet in thickness are of a blood red, and in other cases it shows considerable masses having a structure reminding one of ribbon agate, the thin color layers being red and white and wavy because they are the results of ripple action.

It is commonly fine grained and breaks quite evenly, not only with the plane of stratification, but also in other directions. With properly tempered tools it is capable of quite satisfactory dressing, but it will not generally pay to do so beyond the formation of squared rubble, which is the form of wall usually used.

Some layers are thin and much jointed. These are unsurpassed in durability for paving blocks and rubble. But more commonly the strata are thick, and blocks of any size desired in building may be easily obtained. This massive character of some of its ledges is interestingly illustrated by a great boulder of this rock, known as Pilot rock, near Cherokee, Iowa. It is about 40x50 feet and rises over twelve feet above the surface. This was transported by the glacier at least seventy-five miles without going to pieces.

Extent.—The outcrops of this rock are scattered over a rudely triangular area extending from the northwest corner of Iowa to the latitude of Dell Rapids on the east line of the State, and westward to an apex a few miles southeast of Mitchell. In this area there are probably three or four

square miles of naturally exposed surface, mostly in the valleys of streams. Such exposures have been quite generally worked a little for local use, but nowhere for exportation except at a few localities.

At East Sioux Falls one of the largest quarries is located. It is owned and worked by Messrs. Lowe & Handley, and a general view of it is shown in Plate 23. They are able to obtain blocks of stone of any dimension up to 5x2x14 feet. The prevalent colors are a light pink and a purple or "peachblow" shade.

Near Sioux Falls the State Penitentiary quarries and dresses considerable stone. Messrs. John J. Nysoe and Moses Blum provide also considerable rough stone for local use. The Spencer Stone company at Spencer are actively quarrying building stone for shipment. At Dell Rapids in years past much paving stone has been made, but less activity has been shown lately. In the year 1900 Mr. E. A. Erwin was the only one reporting from that locality. For details of production see summary on a subsequent page.

Uses.—As already mentioned incidentally, it is used for paving, for which it is commended for its durability, but it has been somewhat less used of late because of its harshness on vehicles, its noisiness and its tendency to become slippery. It forms an admirable base for macadam which is subject to heavy traffic, either in block or when crushed. It also forms a very durable element for macadam, but needs to be mixed with some binding material.

For public buildings it is a favorite because of its strength and attractive and unchangeable color. Dirt does not seem to stick to it, and it is practically unfading. Experiments have shown the strength of the typical quartzite to be 25,000 pounds to the square inch.

It deserves high rank also as an ornamental stone. It is capable of perfect and lasting polish, as has been demonstrated by the Drake Polishing company, of Sioux Falls, where they have an extensive polishing plant.

In some localities it grades into a sandstone of light gray color, and sometimes even into plastering sand. Further discussion of these naturally belongs to a subsequent section.

MARBLE.

Four or five miles northeast of Custer and 200 to 300 feet higher than that place there is found an extensive deposit of white marble. It exhibits grades from a pure white, fine grained crystalline rock to coarse mottled variety, with thinner layers of white, beautifully specked with light and dark green, due to particles of serpentine.

It is compact crystalline dolomite, evidently very durable and susceptible of a fine polish.

The deposit is found embedded in and somewhat interstratified with the Algonkian schists. Granite is in some places in contact with it.

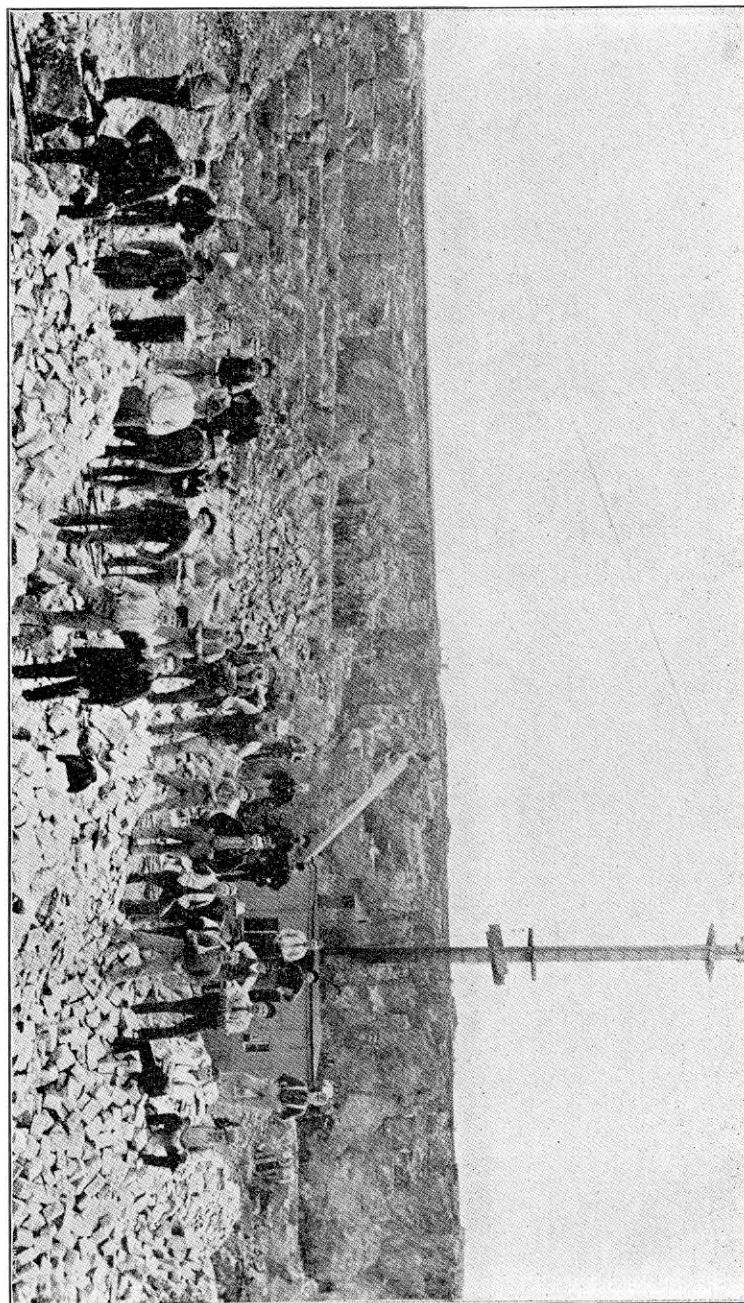
The Black Hills Porcelain Clay and Marble Co. began work early in 1901 and in August had stripped the ledge in three points in a distance of about one mile and a half extending in a nearly north and south direction. The dip varies from sixty to seventy degrees in directions varying from $S 87^{\circ} W$ on the south to $S 70^{\circ} W$ at the north. The last being at the locality shown in Plate 22. The fragments of marble on the surface are said to have been traced on the surface for a distance of four or five miles in an irregular horseshoe-like strip. It is not improbable, therefore, that the portion exploited is on the western side of an irregular anticlinal which eventually may afford a valuable key to the stratigraphical arrangement of the schists.

The marble is in distinct layers from one to three feet or more in thickness, the different layers differing from each other somewhat. Above, they are thinner and more shaly. The serpentine spots also lie in bands parallel with the stratification.

At the southern excavation, granite, rich in albite, seems to have come in contact with the marble below, and by some reaction the feldspar has been kaolinized to a considerable degree. The marble deposit is from thirty to forty feet in thickness.

Another deposit of marble has been found on Box Elder creek in the schist, but has not been developed. So far as ascertained it is of grayish color and mixed with schist. It deserves more careful examination. It is said to be twenty feet thick.

QUARRY OF LOWE & HANDLEY, EAST SIOUX FALLS.



GLACIAL BOULDERS.

East of the Missouri river, and a short distance west of it, are scattered many granite boulders with quartzite, trap and limestone interspersed. These are comparatively rare over most of the surface, or were before they were gathered up, but in certain strips known as moraines they are found in such abundance as will long supply the local demands for rough building stone. Many of the granite boulders are of beautiful colors and very durable. They are often capable of being accurately shaped, and sometimes several cords of stone may be gotten from a single boulder. They have been brought from extensive ledges in Minnesota and Canada.

The terraces of the western tributaries of the Missouri, and even the divides between them, are considerably strewn with small boulders from the Black Hills, and even from mountains farther west perhaps. They have evidently been transported by streams. These are usually much smaller than those brought by glaciers from the north. They are hard and durable, but are rarely of sufficient size to be of much service as building stone, except within a hundred miles of the Black Hills.

LIMESTONES.

There is little limestone worthy the name in our State outside of the Black Hills. The only exceptions are a few strata of clayey limestone of fresh-water origin in the Tertiary of the Bad Lands, and the chalkstone of the Cretaceous, which will be considered by itself.

Again, the most of the limestones in the Hills belong to the Carboniferous age. The exceptions are thirty to fifty feet of a coarse, sandy, buff limestone of the Silurian in the northern Hills, and a gray limestone (Minnewaste) of the Cretaceous, locally developed in the southeastern part of the Hills.

Neither of these require more than mere mention, for they are too impure and irregular in character to be of

value. Perhaps a third might be mentioned in the same connection—an impure, slabby, calcareous, shaly limestone (Greenhorn) which forms a low hogback all around the Hills outside of the more prominent Dakota ridge.

Probably more important than these others, though not as extensive, is a very fine grained white limestone found in the red shale of the Triassic. It has been observed northeast of Whitewood, but is probably found elsewhere in the same horizon. It is beautifully white and very fine grained. Where exposed it was split into layers a few inches thick, but when unweathered it may be compact enough to furnish larger blocks. It resembles gypsum externally, but effervesces freely and is harder. It has not yet attracted attention, but seems well worth careful examination. It is not over twenty feet thick and may not be found extensive.

The limestones of the Carboniferous are exhibited in their stratigraphical relations on page 3, where their characteristics are briefly stated and their relative thickness given.

The Englewood limestone, because of its impure character and thin bedding, does not weather well and is not suitable for either building stone or lime.

The *Pahasapa* or *Gray* limestone is the great source for all purposes, for, though the great mass of it for one reason or another is unsuitable, its great thickness and wide extent and varied character afford many opportunities for valuable quarries. It is said by Darton in his recent report to be about 500 feet thick in the northwestern Hills and about 225 on the east and south. It covers the west half of the Hills, forming a broad table land nearly as high as Harney Peak. Over the east half, it and the Cambrian below have been worn through and so removed by erosion that they form an irregular rampart of high cliffs facing inward toward the central granite ridges and porphyry peaks, and overlooking the lower parks between. As the various streams cut through this escarpment the limestone forms very picturesque canyons, as the noted ones of Spearfish and Elk creeks and scarcely less so of several other

streams. Those mentioned are threaded by railroads, so that the stone is easily accessible.

Much of it is not favorably bedded for quarrying. Strata are so interlocked by stylolites, or by continuous deposition, that masses forty to fifty feet thick may be found, especially in its lower portions. Above it is sometimes brecciated and more siliceous or cherty. But beds of very uniform texture occur, sometimes so white that they have been called marble. Some strata are quite magnesian.

It has not been used to any considerable extent for building for the simple reason that other kinds of rock have been found more available.

Its main uses have been for smelting and for lime. The former has been exclusively by the Golden Reward Consolidated company, of Deadwood. Plate 15 gives a view of the smelter, and to the left of it is seen the lower portion of the Carboniferous, which is used as a flux. It is a dolomite. 14

The following parties have manufactured lime during 1900: Wood & Tipton, Pringle, W. V. Doyle, Doyle, and August Schedine, Deadwood. Their output is shown on a subsequent page. It is also considerably quarried and crushed near Argyle, for ballast on the Burlington railway.

Another limestone called the *Minnekahta* from its relation to the Hot Springs ("Minnekahta" of the Sioux Indians), better known locally as the *Purple* limestone, has lately been shown to belong also to the Carboniferous. It was formerly supposed to be Triassic. It averages less than fifty feet in thickness, but is a prominent feature. It commonly covers the inner slope of the Red valley all around the Hills. It is compact and very fine grain, resembling flint. It is commonly pink tinged with purple, but often streaked or mottled with darker shades.

It is structurally thin bedded and by ordinary weathering breaks into slabs usually two or three inches in thickness. It is often much cracked by folding, and yet it is usually so recemented that it appears like one layer through its whole thickness. Films of clay are found between the thin layers, but stylolytes are so abundant as to effectually interlock the layers nevertheless.

Darton remarks that its color is usually darker on the west side of the Hills, varying from dove color to lead gray.*

Analyses show that the Minnekahta varies considerably in composition, but on the whole is an unusually pure limestone. Prof. H. W. Jensen, of the School of Mines, found it, presumably from the vicinity of Rapid City, to be 98.75 per cent calcium carbonate, and Dr. W. P. Headden found it 95.75 per cent the same.† The impurities are mainly fine sand and iron oxide. Mr. Geo. Stegner, of the U. S. Geological Survey, more recently obtained the following for a typical specimen, probably from the southern Hills:

Analysis of Minnekahta Limestone.‡

Constituent.	Per Cent.
Lime	31.51
Magnesia	19.85
Alumina, iron, etc.....	.36
Water	1.25
Carbonic acid.....	44.66
Sulphuric acid (SO ₃ ) .....	.07
Silica.....	1.12
Manganese, soda and potash.....	none
	98.82

The rock has been used very satisfactorily for lime, and at some points for building. It has been thought that it might be found useful as an ornamental stone, but there has been no serious attempt in that direction as yet. There is little doubt that slabs of considerable size could be sawed from it after the weathered portions have been stripped off, and the variety of color might afford an agreeable mottling. The main difficulty is likely to arise from lack of liveliness of color.

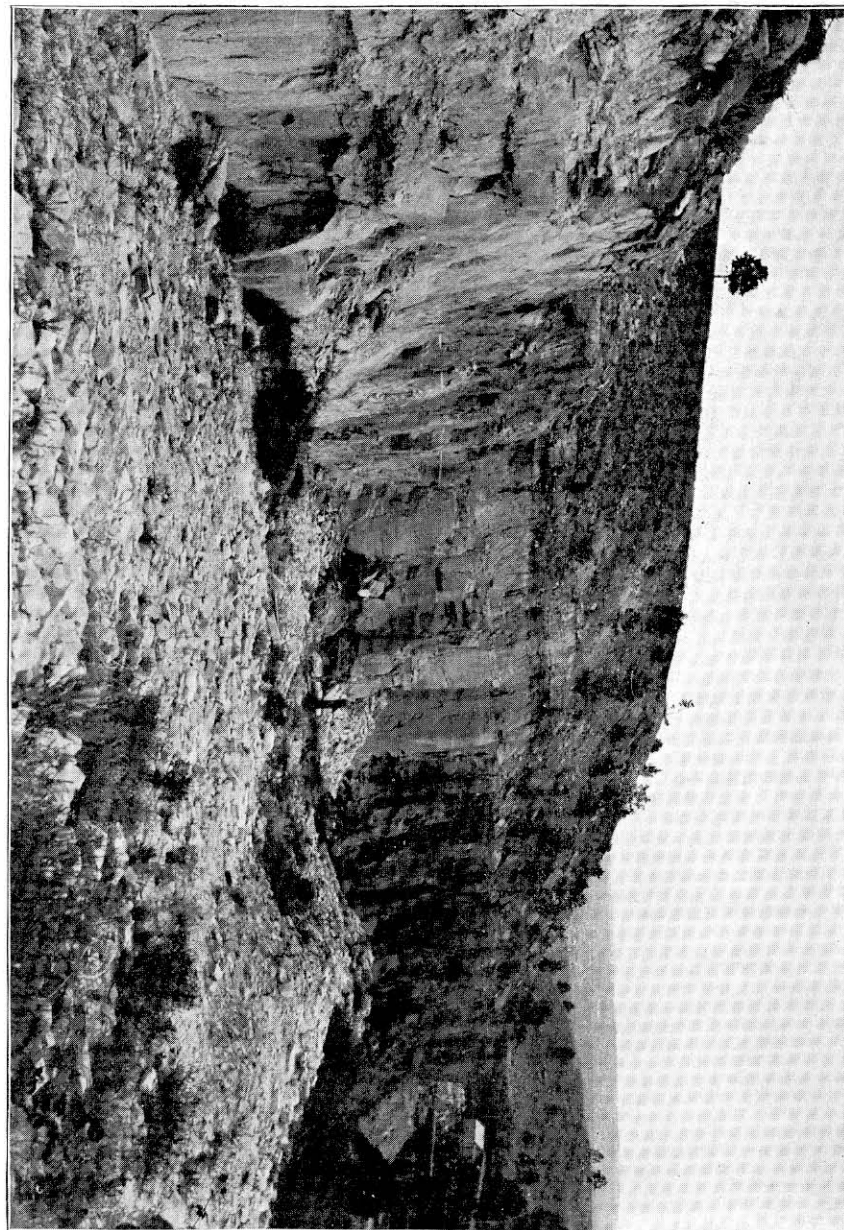
It has been quarried at Spearfish by George Schon for building stone.

A very fine grained white marble closely resembling ivory has been submitted to me by Mr. W. R. Bond, of Custer, who gives the following information concerning it:

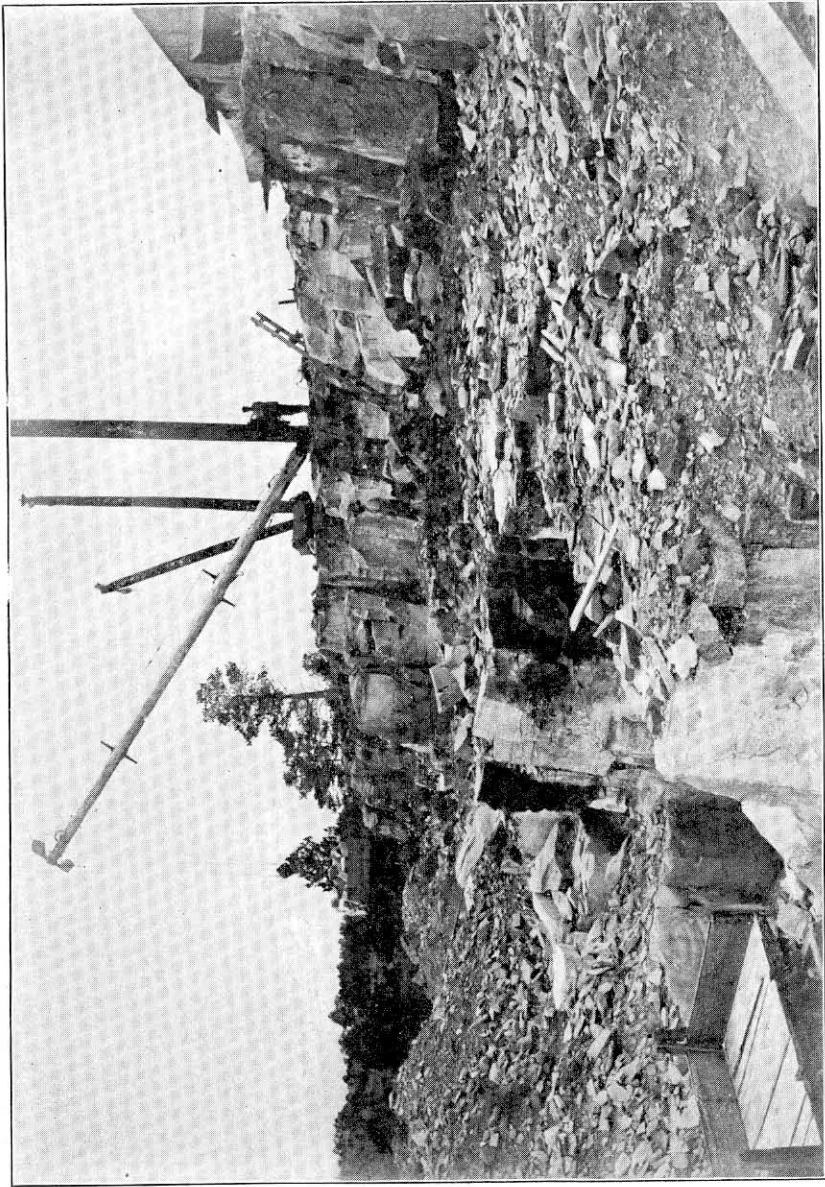
* Twenty-first Annual Report U. S. Geological Survey, Vol. IV, p. 575.

† Carpenter, F. R. Geology and Mineral Resources of the Black Hills, 1888, p. 43.

‡ Darton, N. H. 21st Annual Report, U. S. G. S., Vol. IV, p. 515.



EVANS QUARRY, FIVE MILES SOUTHEAST OF HOT SPRINGS.



BURKE'S QUARRY NEAR ODELL, LOOKING NORTHWEST.

A large porphyry dike has upheaved through the gypsum and brought up the Potsdam. On the top of the Potsdam lies this bed about twenty-five feet thick and showing 500 feet in length. It does not seem to be stratified—it is one solid mass. It is thirty miles west of Deadwood.

This locates it in Wyoming, but the relations are given here to guide for something similar within our borders. It may be metamorphosed Minnekahta limestone, or possibly gypsum changed to carbonate of lime, and similar to the limestone already mentioned as occurring near White-wood.

LITHOGRAPHIC LIMESTONE.

In the upper part of the Pahasapa limestone ten miles west of Custer two or three strata of compact fine grained limestone have been found which have proved satisfactory for lithographic work. The Black Hills Marble and Porcelain Clay Co. has been developing the uppermost of these. Several feet of limestone above have to be removed. The stratum is about four feet thick and lies nearly horizontal. A view of the excavation looking east is shown in Plate 30a. The possibilities of the rock have not yet been demonstrated.

Mr. W. R. Bond, of Custer, has sent in samples from the vicinity of Loring, twelve miles south of Custer, which have proved satisfactory for lithographic work of smaller size. The deposit has not been developed, and how large blocks may be obtained has not been determined.

CHALKSTONE.

This need only be mentioned as a building stone. In early days it was locally used for building at Yankton, Mitchell, Scotland and in a few less prominent towns. Some neat looking buildings still look well after twenty years trial. The material is easily trimmed with a saw or knife, and if well selected is quite durable. Most buildings made of this stone are apt to show here and there a block which has disintegrated. Its disadvantages are its frequently cracked condition and its brittleness. It hardens

by exposure. Quantities of it might be obtained without much difficulty along the Missouri river from Yankton to Chamberlain; along the James; Firesteel, Enemy and Twelve Mile creeks in Davison county; and along Turkey creek in Yankton county. It occurs also sparingly on Brule creek in Union county, near Canton and near Brandon.

Its chief use at present is in the manufacture of Portland cement, and it will be discussed further under that head.

SANDSTONES.

These are especially varied and valuable. Inexhaustible supplies of choice kinds are found in the Black Hills, and varieties suitable for rough building are found quite widely distributed through most of the State.

Specially extensive deposits occur in the Cambrian, Carboniferous, Jurassic, Dakota, Laramie and Miocene. Even older than the Cambrian there are quarries in the Sioux quartzite whose product ranks as a sandstone rather than a quartzite. One of these is in the southern part of Sioux Falls. The stone is somewhat porous, of medium grain and fine texture. It is of light flesh color to light gray. In some localities this rock becomes quite friable.

The Cambrian sandstone is finely exhibited in Plate II. This formation underlies the Carboniferous limestone and is commonly exposed more or less at the foot of the main escarpment facing the interior of the Hills all around. Some layers, particularly toward the top and bottom, are thick bedded enough for building purposes. The intermediate portions are quite apt to be too shaly. This rock has not recommended itself for use to any considerable extent, except because of its vicinity in some cases. It is not of attractive color, and is apt to be of uneven texture.

The *Minnelusa* Sandstone, in the upper part of the Carboniferous is a series of more than 360 feet consisting mostly of sandstones, varying in color so much that they were called *Variiegated* Sandstone by Newton. Red, yellow and purple are often represented. The stone varies much in

hardness and composition. Mr. Darrow, of the firm of Darrow & Mowatt, informs me that at Doyle, where they have opened quarries, some strata rival the Sioux Falls quartzite in hardness. This is exceptional for this formation. The rock is generally much softer. The following table exhibits the testing of the different qualities of stone in the Darrow & Mowatt quarries, made by John Muckley, of Omaha, Neb., in 1894:

Table Showing Strength of Sandstones from Darrow & Mowatt Quarries, Doyle, S. D.

No.	Kind.	Average Strength lbs. per sq. in.	Remarks.
1	Pink No. 1.....	5,670.6	Failed without report.
2	Pink No. 2.....	4,285.	do.
3	White	13,960.6	Failed with loud report.
4	Red, fine.....	20,575.5	do.
5	Red, coarse.....	8,318.	

Samples tested at the United States arsenal at Watertown, Mass., from this same locality give the following:

Kind.	Strength per sq. in.	Remarks.
Pink	10,532	Black Hills Quarry Co.
Buff	8,401	do.
Light drab.....	5,937	do.

The red coarse has been used for trimming public buildings in Lead, and has shown that it stands fire well. It has seams eight to twenty-four inches apart. The quarries are favorably situated near the station Doyle on the Burlington & Missouri River railroad. Doubtless similar quarries might be opened at a dozen points where the different streams traverse this sandstone which surrounds the Hills.

The *Unkpapa* Sandstone, of the Jurassic, is less regular in thickness than most other formations; is sometimes lacking or so soft that it does not show itself as an outcrop;

but at certain localities is remarkably developed, being sometimes 100 to 150 feet thick, though commonly not over twenty-five feet. It is usually remarkably massive, showing little trace of layers. It is soft, but remarkably uniform in color and size of grain for many rods. The colors found are bright red, white, yellow and variegated, the last showing thin lines of pink and red corresponding to the stratification, often crossed at a large angle by dark lines, perhaps due to faulting, in a way which reminds one of a plaid. The red has proven itself stronger and more durable. All varieties carve beautifully. Plate 26a gives a general view of a mountain of this sandstone southwest of Buffalo Gap, where considerable stone was taken a few years ago. It is not now worked. The white and yellow varieties seem to follow a fissure, as though at some time they had been subject to chemical action which hydrated or removed the iron oxide which gives the general red color. This would agree with the diminished cohesion of the grains.

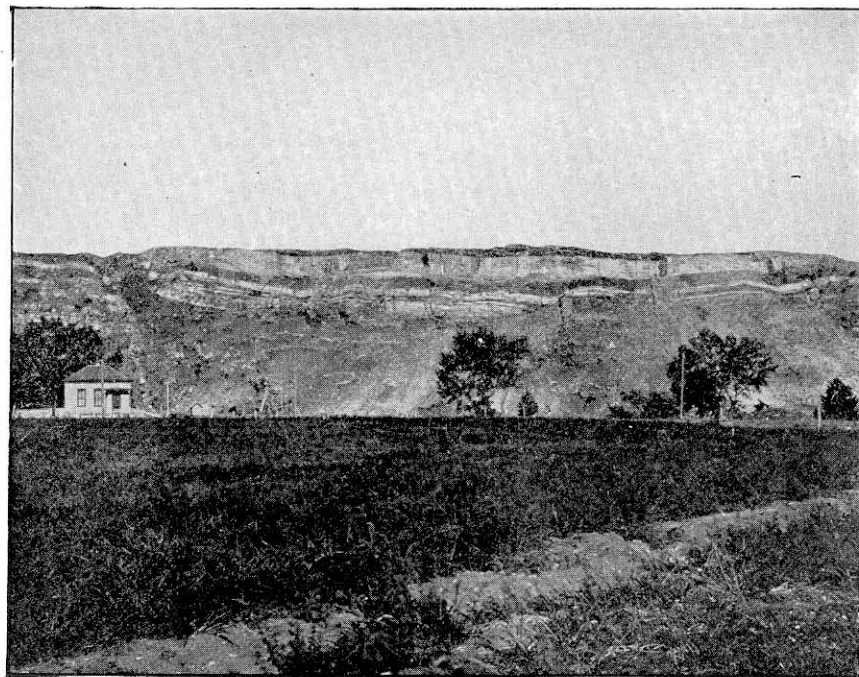
The *Lakota* Sandstone is the name by which it has been recently agreed to designate the lower and thicker member of the heavy sandstone formation formerly and still quite generally known as the Dakota. It is a massive buff sandstone, coarse grained and often cross bedded. It is parted by occasional layers of shale several feet in thickness. The whole formation is from 200 to 300 feet in thickness, according to the locality. It has not been much quarried. Neither in quality nor color is it attractive, though local beds may sometimes pay for working.

THE DAKOTA SANDSTONE.— It has been recently agreed to limit this name to the upper member of the heavy sandstone formation first named the Dakota by Dr. Hayden. It is that which has been most quarried about the Black Hills. It is well exposed in all canyons cut through the main hogback surrounding the Hills, and also on the outer slopes of the same ridge throughout. Because of its topographical relations, it is the most exposed of the sandstones of the Black Hills.

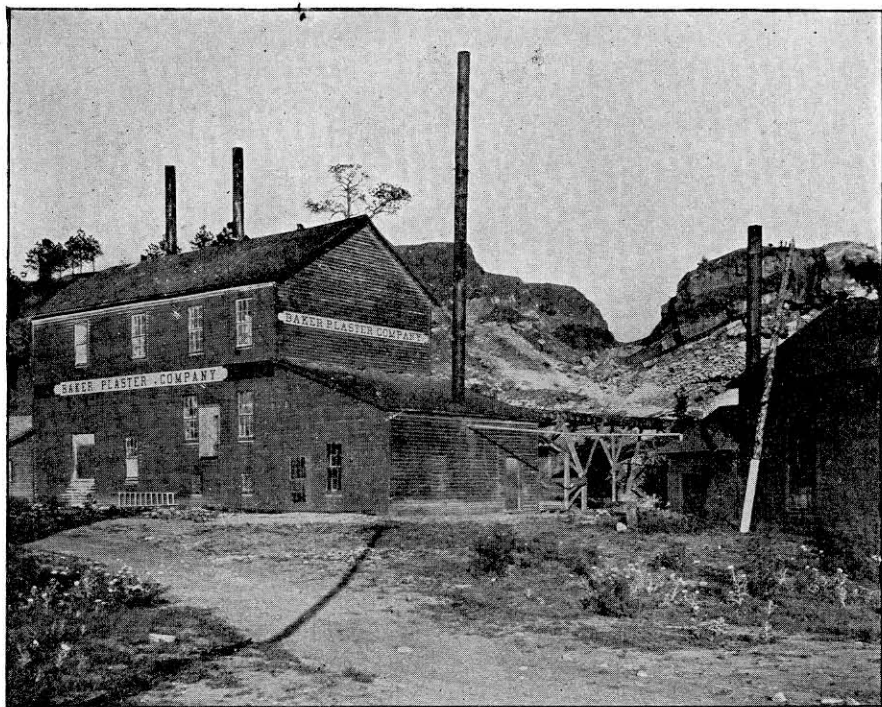
Some of the more prominent quarries which have been



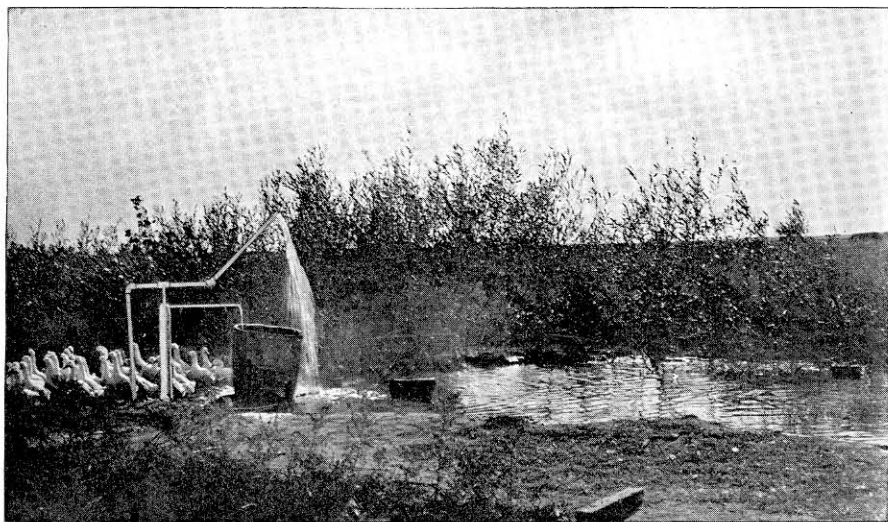
a.—ELM CREEK QUARRY IN JURASSIC SANDSTONE.



b.—GYPSUM LAYERS OVER TWELVE FEET THICK, ONE MILE NORTH OF HOT SPRINGS.



a.—WORKS OF THE HOT SPRINGS PLASTER COMPANY, HOT SPRINGS.



b.—ARTESIAN WELL FURNISHING BOTH HARD AND SOFT WATER.

Seven miles northwest of Mt. Vernon.

worked are in this stone. Perhaps the most notable is the Evans quarry, five miles southeast of Hot Springs. From it was obtained a pink and light gray sandstone, out of which the finer buildings of that place have been constructed. It is massive, easily worked, and a stronger stone than the Unkpapa. Samples at the Columbian Exposition tested at the U. S. ordinance department at the Watertown arsenal, Mass., showed a strength of 6,305 pounds to the square inch, and the test stood 7,491 before yielding. A view of the Evans quarry is shown in Plate 24.

More recently the Burke Stone company, which had been working the Evans quarry, in 1899 transferred their efforts to a point two or three miles further north, where the higher part of the ridge is faced with a sheet of excellent stone, twenty feet or more in thickness with a natural front, which is afforded by a ravine extending from top to bottom of the eastward slope.

The prevalent color of the stone is called a "pearl grey," almost white. A mill for sawing the stone is built near the railroad at the foot of the slope and the stone is run down the slope by a gravity tramway. There are two gangs of saws. The works are equipped with steam derricks and stone are landed directly on the cars. Tests of this stone made at the Watertown arsenal, Mass., Oct. 25, 1900, show that the strength of the stone is 8,047 pounds per square inch, and the chemical composition is 97.75 per cent silica and 2.20 per cent alumina.

In the same formation is the quarry of L. E. Thoen on Lookout mountain, at Spearfish, which has been worked many years. Samples tested in 1893 as before mentioned showed a strength of 4,516 pounds per square inch. It is of a light grey color, a handsome stone.

An extensive quarry was opened several years ago three and one-half miles north northwest of Edgemont, from which much fine building stone was taken. Certain strata made excellent *grindstones*, but the works are not now in operation. Other strata are said to have furnished *hone-stones* of fine quality well adapted for sharpening razors. The quarry is unusually well situated on a high bank north

of Red Canyon with good drainage and plenty of room for removal of waste. The dip of the strata is toward the southwest at a low angle.

Near Rapid City a good quarry in the Dakota has been worked for local purposes.

A rusty sandstone of irregular structure believed to belong to the upper portion of the Dakota displays a thickness of twenty to thirty feet along the James river in Hutchinson county and along the Firesteel and Enemy creeks in Davison county. Some layers of it are quite durable. It is used successfully for foundations and rough building, and to small extent for more pretentious structures.

LARAMIE SANDSTONE.—In the upper portion of the Laramie stage of the Cretaceous is a notable massive buff sandstone forty to fifty feet in thickness, capping the Cave hills as shown in Plate 31. It has good color and fair strength and durability, as shown from its natural exposures.

Thinner beds are also found lower down and also in the Fox hills below. These are often exposed on the tops of buttes and mesas in the northern half of the State. They will serve a good purpose in meeting the ordinary demands of local building as the region settles up.

TERTIARY SANDSTONES.—Thin strata of light gray sandstone of coarse and irregular structure varying greatly in hardness, are scattered through the White River and Loup Fork beds in the southern half of the State. They are somewhat similarly situated and will serve a similar purpose to the Laramie and Fox Hills strata first mentioned.

Cements and Clays.

Under this head we include all deposits which furnish fictile products, or contribute to ceramic work. Moreover, all need to pass through the fire to accomplish their purpose. As regards their raw condition, the cements shade into building stone through limestone, chalk and gypsum, and into clays on the other hand. What we call cements are first burned, which gains for them the property

of solidifying or setting when moistened on account of the lime in their composition. Clays on the other hand are rendered plastic by water and are hardened by burning.

CEMENTS.

Of cements we enumerate lime, plaster and Portland cement; and of clays, kaolin, fire clay, potter's clay, brick clay and fullers' earth.

LIME.—This has already been briefly mentioned under the head of limestone. About 28,500 bushels of lime were made in the Black Hills in 1900, valued at \$8,500.

GYPNUM.—This so abundant that it might have been discussed as a building stone, for which it might be used, but it more naturally falls under this head. It is found in extensive deposits, both as regards thickness and breadth, in the red marly clay of the Spearfish formation. Its white masses often show in pleasing contrast with the surrounding clay. Plants were erected several years ago at Hot Springs and Sturgis for preparing it for plaster. Only the former has been worked for several years, and that not to its full capacity. The mills of the Hot Springs Plaster company, J. M. Brelsford manager, are shown in Plate 27a. Their raw material is obtained conveniently from the cliff back of the mill. It occurs in ledges of from ten to forty-four feet thick, with from four to six feet of red clay between. Three such ledges are in sight, and there is evidence of a fourth below. A view of a similarly situated deposit about a mile further north is shown in Plate 26b.

The mill has a capacity of forty tons a day. The products made are as follows:

1. *Stucco.*—This is calcined and ground gypsum, which will set in eight to ten minutes.
2. *Plaster.*—Another variety so mixed that it will not set for forty-five to fifty minutes.
3. *Dental Plaster,* of choice quality and very finely ground. It will set in six minutes.

Products of this mill are sold in Nebraska, Colorado, Wyoming, Montana and South Dakota. Handsome carv-

ings from the natural gypsum, or alabaster, are made by veterans in the Soldiers' Home.

Veins of gypsum in the form of satin-spar occur in the Bad Lands, and search may discover some of thickness sufficient for profitable working, but none over six inches in thickness have yet been reported.

PORTLAND CEMENT.—The material used for the manufacture of this most valuable product is chalkstone of the Colorado Cretaceous and a dark, fat clay overlying it, commonly referred to the Pierre or Montana epoch. Clay is also found below or in the chalk.

While the material is quite widely distributed, the plant near Yankton is the only one which has been erected. It was built in 1889-90. A general view of this plant is shown in Plate 28. The cliff of chalk is shown in the background. The capacity of the plant is 250 barrels a day. It is estimated that 250,000 barrels had been put on the market before 1899. The product for 1900 was 39,500 barrels (380 pounds each), worth \$80,000.

The method of manufacture employed is known as the semi-wet process, which is thus described by Mr. Andreas Lundteigen, chemist of the company:

The chalk and clay are weighed separately in their natural moist state, when they contain 25 to 30 per cent of water. They are then shoveled into crushing and grinding machines where enough water is added to make the mixture, called slurry, run somewhat freely into very large tanks with a capacity of several hundred thousand pounds. After being stirred and mixed well the slurry is elevated into other grinding machines, where it is reduced to extreme fineness. Frequent chemical tests are made to insure the exact composition of the slurry. For this purpose small samples are dried and weighed, and the carbonic acid is determined, or the samples are dried, burned, crushed, ground and analyzed for lime and silica, a process that requires about two hours. According to the results of each analysis the scales are adjusted, and in this way a uniform composition can be maintained, although that of each of the raw materials may vary. The slurry is pumped into drying tunnels, to be dried by the waste gases from the kilns, or it is pumped into open level squares on the ground to be dried by the sun and the dry Dakota winds. The slurry shrinks and cracks by drying into blocks weighing from ten to fifty pounds. These are piled up in sheds for further drying or storing, or they are conveyed to an overhead tram-

way directly into large pot kilns, which are filled by placing alternate layers of coke and broken up lumps of slurry. There are six of these kilns at Yankton, each burning about 310 barrels of cement at a time. While it is sufficient to burn hydraulic or natural cement only until the most of the carbonic acid is expelled, it is essential to Portland cement that the burning is carried to incipient fusion, which makes the burning of this cement a very costly process. The greenish black honey-combed clinker is as hard as granite and very heavy. It is wheeled into a strong iron crusher, in which it is reduced to the size of hazelnuts. From the crusher it passes through two sets of steel rolls, which reduce it further to the size of rice, after which it is finally ground to impalpable powder (cement) by burr stones. The cement is carried by revolving steel conveyers into warehouses. A daily test for soundness and strength is made, which gives the operators perfect knowledge of the quality of the cement in stock.

Should there develop a demand sufficient, similar plants might be developed at a score of places along the Missouri and James rivers. (See the distribution of chalkstone given in a previous section.) The product of the Western Portland Cement company has an excellent record, and cement walks and walls and other works are increasing in favor.

SLAG CEMENT.—A cement may be made by grinding together furnace slag and slaked lime. This product is quite extensively manufactured in Illinois, Ohio and Maryland.* No attempt of this kind has been made in our State, but favorable localities are not wanting. At the Golden Reward smelter (Plate 14) abundance of slag and limestone are in close relation and favorably situated for transportation.

CLAYS.

Clays abound in our State, but have been little utilized and have not been systematically studied. The State is largely covered by the Cretaceous formation which here as elsewhere is mainly clay. When clay becomes the main building material, as eventually happens in every country, no doubt this resource will be found admirably fitted to the need.

We will under each item note the present development

* Twenty-first Annual Report U. S. Geological Survey, Part VI Continued, p. 403.

and the future possibilities so far as our limited knowledge may indicate.

KAOLIN OR CHINA CLAY.—Samples of a clear white clay have been received from Mr. W. R. Bond and Mr. A. H. Smith, of Custer, from different localities near that place. One of these, which is owned by the Black Hills Porcelain Clay and Marble company, has been explored by a shaft to the depth of eighteen or twenty feet. The deposit appears to be a decomposed feldspar, mostly in original position, but in part rearranged. In samples examined some were quite infusible, but most give a strong yellow flame and were quite easily fused to a white enamel.

From these facts and a hasty examination of the locality, it is inferred that the deposit is due to a weathering of a vein of granite, which elsewhere, as at the Etta mine, is known to be locally mainly composed of albite. It is claimed that practical tests have found it a choice clay. Its easy fusibility and whiteness may recommend it for a bond clay or for medium grades of ware, but hardly for the highest grades. In the locality visited it is in close proximity to the marble and apparently underlies it.

Kaolin elsewhere has been connected with veins of pegmatite or "graphic granite." These are known to abound in the Harney Peak and Nigger Hill regions; hence we may expect the discovery of other and perhaps more important deposits than those yet reported.

FELDSPAR.—Quantities of albite, or soda feldspar, occur at the Etta mine, and at other mines. It is in large crystals, quite pure, associated with spodumene, which is also a valuable product. (See page 75.) This may be used after grinding for similar purposes as china clay. The soda variety fuses more readily than the potash or flesh-colored or reddish feldspar, orthoclase. No attempt has been made to utilize it, but it is a promising mineral.

FIRE CLAYS.—Under this head are included clays which will resist a high temperature without fusing. The degree which may be set as a minimum limit of fusion is 2700° F., though some so-called fire clays fuse as low as 2300° or 2400°.

So far as yet ascertained, the fire clays of the State occur mainly in the Fuson formation. There are three or four horizons which seem the best developed in the vicinity of Rapid City, though they are known to occur also at Hot Springs and probably at other points.

Prof. C. C. O'Harra informs me more definitely that with one exception all of the beds developed near Rapid City are in the Fuson formation. The exception is in the top of the Unkpapa sandstone, a soft, massive rock, which is there argillaceous enough to serve as a fire clay. It was opened on the north side of Rapid creek just above the electric light reservoir, but after considerable working it has been abandoned.

The deposits in the Fuson include much of that formation, but most of the openings have been made near the middle of the formation. Southwest and south of Rapid City several gulches cut back from the east into it and have afforded good exposures. In Powder House gulch at least forty feet of the middle beds are now being worked. Further exploitation would doubtless disclose still greater thickness. The workable beds on Rapid creek are perhaps fully as thick and have been developed almost as extensively.

The only practical testing of material has been done by Mr. C. A. Marshall, who has erected a quite extensive plant (see Plate 29a) and has manufactured fire brick of various forms, which has been found equal to any imported into the Hills. He has control of several beds and has been systematically experimenting to ascertain the best constructions for particular results. Some deposits are extremely refractory, while others are more easily fusible and more easily rendered plastic. All show the compact, light gray appearance and conchoidal fracture usually distinguishing fire clay.

The beds dip to the east at a high angle, and when exposed on a west slope will need to be mined, but there are extensive exposures on east slopes where many square rods are easily accessible. A characteristic view of such exposures is shown in Plate 29b. This particular locality, moreover, has furnished the most satisfactory clay.

Dr. R. A. Slagle has kindly furnished from the records of the School of Mines the following:

Analyses of Rapid City Fire Clays.

	1	2	3	4
SiO ₂	87.050	83.30	76.78	81.98
Al ₂ O ₃	6.560	12.30	14.43	13.08
Fe ₂ O ₃ .....	.640	.80	.18	.21
C ₂ O .....	.950	1.30	2.18	1.46
MgO	1.243	trace	.95	.31
Alkalis	3.008		trace	trace
Loss on ignition	1.800		4.62	4.07
	101.251	99.40	99.14	100.86

Nos. 1 and 2 are varieties tried at an earlier stage of experimentation. No. 3 is from the east slope of ridge, middle Fuson, the locality shown in the plate. It has given the best results. No. 4 is from Rockerville hill, the upper softer part of which is serviceable for cementing the harder varieties.

On general principles it seems possible that the under clay of the lignite beds of the Laramie in the Cave hills may afford refractory clays, but no search has been made in that direction.

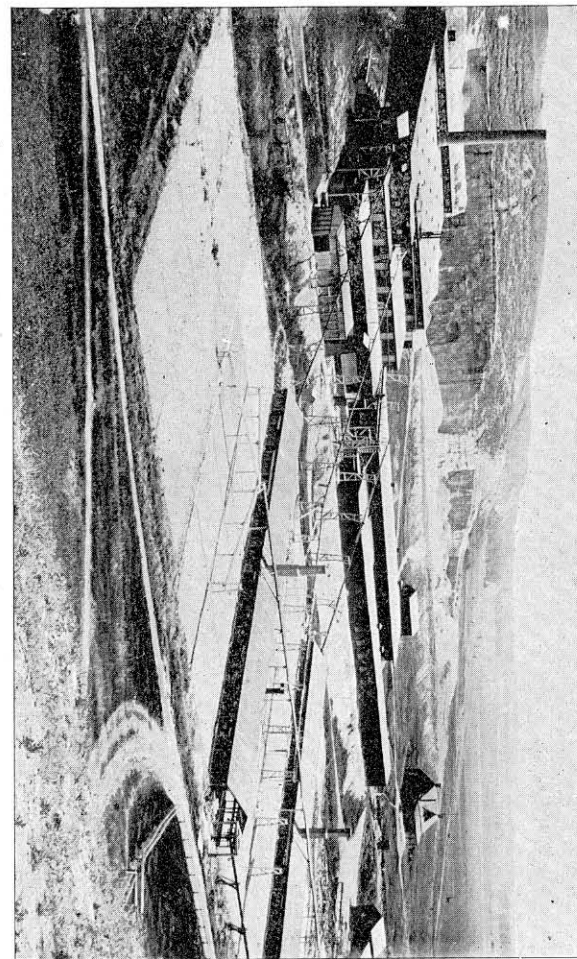
POTTERS' CLAY.—No systematic search has been made for this material, but it is probable that any desired quality may be found in inexhaustible quantities. Drab and gray shales abound in all the Cretaceous formations, particularly the Fuson, Dakota, Pierre and Laramie, while in the Tertiary lighter and more calcareous clays abound.

These materials are distributed in all parts of the State. East of the Missouri, however, the covering of glacial deposits renders them generally inaccessible, except in favorable localities along the larger streams.

The Pleistocene is too heterogeneous to serve for this purpose, because of included pebbles or lime nodules.

BRICK CLAYS.—Brick have not yet been very extensively manufactured in South Dakota. Over much of the State, particularly in close proximity to the principal towns,

WORKS OF THE WESTERN PORTLAND CEMENT COMPANY NEAR YANKTON.



good brick clay is not very accessible. This results from the fact that settlements have been mainly made in the glacial region east of the Missouri and in the mountainous region of the Black Hills, where clays are generally stony because of their proximity to the original rocks. In the regions between, where clay is more abundant, population has been small and fuel scarce; hence few attempts have been made to utilize the clays of the Montana and Laramie, which are most promising for the purpose.

Nevertheless, many brick of fair quality have been made, and when once constant demand shall justify the engagement of experienced workmen and the erection of suitable plants, as in older States, we have no fear that suitable materials will not be found in abundance.

The term 'brick clay' is not very definite, but may be used to include the darker colored and more easily fusible clays—those which by moderate heat (1800° or 1900° F.) are rendered sufficiently coherent for building purposes, or vitreous and tough for paving or tiling.

Color, also, both its shade and permanence, is a very important characteristic, particularly for front or pressed brick.

Material hitherto used for brick-making in our State has been mainly from alluvial deposits either of the Pleistocene epoch or more recent.

The following is a list of the brick makers of the State, beginning with some of the older and more permanent plants:

W. G. Bower, Vermilion, Clay county, has a plant furnished and equipped with two ovens for making common brick, pressed brick and paving brick. The material used is the alluvium at the old junction of the Vermilion and Missouri rivers, a few feet above the water. Satisfactory results were obtained from Benton shales from the southern bluffs of the Missouri, but they are too far away to be used economically.

C. A. Marshall, Rapid City, has already been mentioned in connection with fire clay. He, however, manufactures common brick and pressed brick. The material used is derived from different sources, mainly from clays selected from the Red valley, mostly re-deposited as alluvium; but for giving a satisfactory red color, clays probably from the Permian are used.

W. E. Cone, DeSmet, manufactures common red building brick from a yellow clay, doubtless of alluvium, possibly deposited in the Glacial period.

W. R. Mason, of the same place, common wall brick, probably from similar material.

The Big Stone City Brick Co., of the city of that name, manufactures common brick, probably from material of similar deposition to the preceding.

H. R. Fregert, Englewood, W. E. Butler, Lead City, and Brown & Robinson, Hill City, are all manufacturing brick, probably from the silt in the valleys where they are located respectively; but, judging from the last, which was the only one visited, the material is neither most favorable nor abundant.

Attempts to manufacture satisfactory brick economically have been made at Chamberlain, Pierre, Mitchell, Yankton and several other points with indifferent success, so that operations have been discontinued. The usual difficulties found with drift clays are the small pebbles and concretions which are apt to occur, which not only interfere with the moulding of the clay, but if they consist of lime they will split the bricks by slaking after burning. Moreover, the color is not likely to be good. Similar difficulties attend alluvial deposits if they are too coarse, as is frequently the case near rocky strata, as in the Black Hills.

The shales of the Cretaceous may not be so easily worked, but doubtless in many localities would give good results; and the plastic clays of that age, while working more easily, if mixed with sand prove satisfactory.

In Iowa and Nebraska good building brick are easily made from a yellow loam called loess. It needs to be selected, so that it will be free from lime nodules, which are not uncommon in it. Extensive deposits of this occur in Union county, and a very similar deposit caps some of the terraces of the Missouri at and above Pierre. Strata of a similar buff loam occur in the Laramie formation in the northwestern part of the State.

At some points in the Black Hills extensive beds of loamy material have been accumulated by the winds, which resemble loess and should be tested for this purpose. One of these is at Chilson siding on the B. & M. railroad.

In the upper strata of the White River bad-lands there are also abundant loams which, if not too calcareous, may make good brick, probably of light color because of lack of iron.

FULLERS' EARTH.—This is a peculiar form of clay which was formerly used for cleansing cloth from grease; hence its name. In later years it has been used perhaps more for clarifying oils by filtration and is in good demand. Much that is used in this country is imported from England; some is obtained in Florida. Its value depends more upon its physical properties than its chemical. It is a spongy clay, rather than plastic. It may vary much in color. In the Twenty-first Annual Report of the U. S. Geological Survey it is stated that "the earth discovered in South Dakota is almost the exact duplicate of the English earth, and will no doubt become a valuable substitute for it."* Mr. Darton, of the U. S. Survey, in his recent paper on the Black Hills, says:

In the Chadron formation adjoining the Black Hills there are thousands of square miles of deposits having the chemical and physical properties of fullers' earth, but it is not known what proportion of the material is available for commercial use. Mining operations were begun at a point three miles southwest of Argyle, and on the east side of the Hills three miles south of Fairburn, but the first shipment failed to yield satisfactory results in the factory tests. It is claimed by owners of the Argyle property that their trial shipment was not selected with sufficient care to exclude extensive admixture with the more sandy associated beds, and the failure at Fairburn appears to be due to a similar hasty shipment without careful selection of the best material. As tests of the small samples were satisfactory, the miners supposed that the earth was all serviceable and did not discriminate in making a bulk shipment. It is desirable that further trial should be made of the earths on a larger scale, and that the shippers should be guided by careful sampling and testing, so as to be able to select only the very best material obtainable. Proper powdering and drying are also to be considered. The fullers' earth deposits extend from the high slopes of the hills west of Fairburn and Hermosa far eastward into the Bad Lands. The deposit southwest of Argyle covers an area of at least 1000 acres. The tests made of small samples of these earths from Argyle and from the beds a mile northeast of Fairburn have given excellent re-

* Twenty-first Annual Report U. S. Geological Survey, Part VI Continued, p. 591.

sults with cottonseed oil, and, as they possess all the characteristics of genuine commercial fullers' earth, they deserve to be carefully developed.

The following are analyses of some of the fullers' earth deposits, taken from a paper by Henrich Ries:*

Analyses of Fullers' Earth from South Dakota.

Constituents.	1	2	3	4
Silica	68.23	60.16	55.45	58.72
Alumina	14.93	10.38	18.58	16.90
Ferrous oxide	3.15	14.87	3.82	4.00
Lime	2.93	4.96	3.40	4.06
Magnesia .....	.87	1.71	3.50	2.56
Loss on ignition .....	.20	7.20	8.80	8.10
Volatile			5.35	
Alkalis				2.11
Moisture				2.30
Total	96.31	99.28	98.45	98.90

Analyses 1 to 3 were made by Prof. Flinterman, South Dakota School of Mines; 4 by Mr. E. J. Riederer. No. 1 is from Wm. Bodener's pit north of Fairburn (which is shown in Plate 30b). 2 from M. Palmister, Fairburn; 3 from D. Henault, Custer, from Argyle mines; and 4 from southeast of Fairburn.†

These beds seem to have been formed in the valleys of the Cretaceous clay before the mass of the Tertiary was laid upon them.

VOLCANIC ASH.

This material has similar properties to pumice stone. It differs from it mainly by having been so much inflated by steam or other gases at the time of its ejection that the bubbles in the former were burst, pulverizing their walls into very minute particles, which were carried in the air for great distances, and when dropped into still water

* The Fullers' Earth of South Dakota. Trans. Am. Inst. Min. Eng. 1897.

† Twenty-first Annual Report U. S. Geological Survey, part IV, p. 588.

formed very pure and often quite thick beds of a snow white or light green ash-like material.

Mr. Darton, of the U. S. Geological survey, reports it from several levels in the White River formation in Nebraska and this State. He states that a bed three feet thick is found near Argyle, and that a limited deposit of fine quality occurs near Oelrich.* He also informs the writer that strata of it occur near the tops of Sheep and Cedar mountains in Washington county. A stratum ten or twelve feet thick extends some distance along the South fork of White river in Lugenebeel county.†

This material is used like pulverized pumice for a polishing powder and for mixing with soap for scouring.

Like trass and pozzuolana, it may be used for strengthening cement and mortar and making them more durable. It seems probable that it may also be utilized for making a valuable glass.

SAND AND GRAVEL.

Deposits of sand and gravel abound along the streams in and near the Black Hills, not only in the channels but often in larger deposits along the tops of the high terraces. In the eastern portion of the State similar deposits are found along the terraces and channels that were occupied by streams in the Glacial age. Over portions of the State covered only with Cretaceous clays, sand may not be easily obtained for local needs, but upon the Tertiary and Laramie areas little trouble will be found in this respect.

GLASS SAND.—Besides the volcanic ash already suggested as possibly available for this purpose, may be mentioned extensive masses of the Unkpapa sandstone on Elm creek, which by leaching have been rendered incoherent and of a clear white color. They appear in Plate 26a.

* Nineteenth Annual Report U. S. Geological Survey, Part IV, p. 760. and Twenty-first Annual Report, Part IV, p. 591.

† Bulletin No. 2, South Dakota Geological Survey, p. 128.

Mineral Fuels.

Under this head fall coal, lignite, peat, petroleum and gas. These as a whole are but feebly represented in our State, and so far as known are wholly obtained from the Cretaceous formation.

COAL.

The Carboniferous rocks in the Black Hills show no trace of coal. Evidently during that age this region was open sea, far from land, at least without marshes favorable for the formation of coal. As the eastern end of the State was at the same time dry land, it follows that the shore line lay somewhere between, crossing the State from north to south. It is not unlikely that along that line those marshes existed and beds of coal were formed. However, they will never be accessible, for they are below the copious artesian waters which underlie our State. They deserve no mention except to suggest their possible connection with the gas supply as will be more fully detailed on a subsequent page.

In the Lakota, traces of coal have been found at several points around the Black Hills. The more important are in the neighboring State of Wyoming about New Castle and on Hay creek, but workable beds of fair quality of bituminous coal were opened along the Cheyenne east of Edgemont several years ago, and several tons were taken out; but the locality is difficult of access and not thought extensive enough to justify building a railroad to the place. Mr. Darton in a recent report to the government covering this area says:

In the gorge of the Cheyenne river below Edgemont the coal beds have been opened at various points. On the south bank of the river three miles below the town a drift has been run in on a thin bed of coal in the basal portion of the Dakota sandstone fifty feet below the top ledges of this formation, in which a thickness of three feet of coal of fairly good quality is exposed. Beginning at the second bend of the river, five miles southeast of Edgemont, where the stream is flowing nearly due south, there are a number of coal openings in the bluffs on the east bank. From one to three feet of variable coal is exhibited in the first series of prospect pits. In the bend where the river turns east northeast again, there is a mine

which has been worked to a small extent, exhibiting four feet of coal lying in a basin which is seen thinning out to the east. There are two tunnels about seventy-five to one hundred feet in length, along which the coal varies in thickness from four to five feet. It lies between massive, light colored, fine grained sandstones, about forty feet above the base of the Lakota formation. The beds dip very gently to the southeast. Small showings of coal occur in the deep canyons northeast of this locality, but the beds are very thin and impure. Apparently this was at the southeastern margin of the area in which the conditions were favorable for coal accumulations at the time of the deposition of the Lakota formation.*

At probably the same horizon, beds a few inches thick have been discovered near Rapid City, Whitewood and southwest of Minnekahta.

The only chance for finding workable beds in such localities is the possible occurrence of "pockets" of very limited extent. Such occurrence is extremely improbable.

LIGNITE.

This term is used to designate a comparatively light and porous carbonaceous deposit. It burns easily with a flame, is often of a brownish color, and hence is sometimes called brown coal. It presents characteristics intermediate between bituminous coal and peat, but is nearer the former. Frequently pieces of it show bright lustre and are as clean as anthracite. They are pieces of carbonized logs.

Adjoining the eastern end of the State a porous coal more properly called lignite has been found in thin beds about Sioux City and near Ponca, Neb., where, despite their thinness, they were formerly worked in a desultory way. Probably from the same geological horizon similar beds have been reported at a few points in Yankton, Clay and Turner counties, but they are illusive. They are of inferior quality, thin, and flooded with artesian water. They lie in the upper part of the Dakota formation.

In the northwestern corner of the State, in the Laramie formation, are numerous layers of lignite varying in thickness from a few inches to ten or eleven feet. Many of the beds are too thin to have value; others, though thick, are

* Twenty-first Annual Report U. S. Geological Survey, Part IV, p. 583.

too impure. A frequent difficulty is the lack of suitable roof for mining. Moreover, the strata vary much in quality and thickness within short distances. In some cases they have been burned out quite extensively, leaving horizontal lines of brick-like clay or slag-like fragments in place of the thick beds of lignite, which originally existed. However, at several points the lignite is pure, with good lustre and angular fracture, and of good thickness. In a few localities it may be quite extensively uncovered with a scraper.

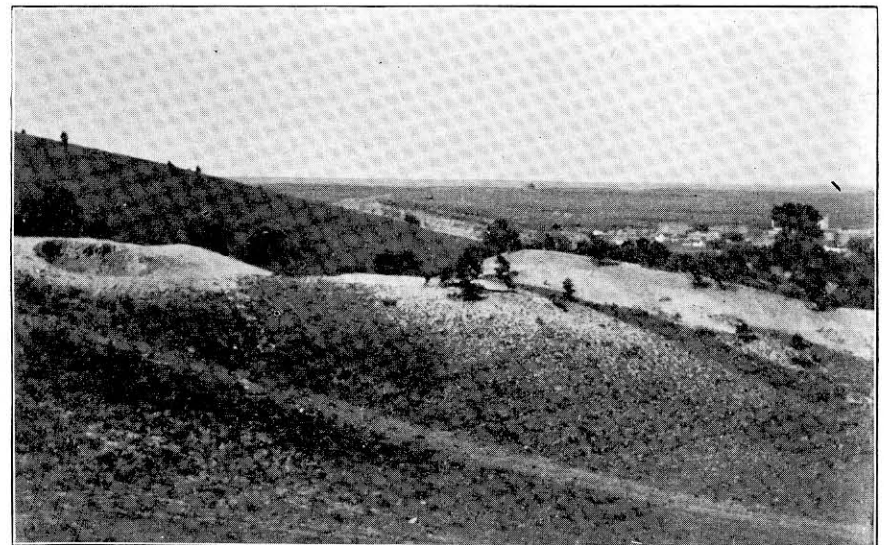
In Plate 31 is shown a view of the south end of the North Cave hill. It exhibits in connection with the following section a fair representation of the strata to be found about the Cave hills, Slim Buttes and to some extent in the Short Pine hills.

Section of the South End of North Cave Hills.

1. Yellow, fine grained quartzite or flint	2 feet
2. Whitish marl, with thin layers of limestone above.....	18 "
3. Purplish massive sandstone.....	27 "
4. Gray and white plastic clays.....	12 "
5. Yellow massive sandstone and sand, mostly the latter below fifty feet	79 "
6. Dark plastic clay with a nine-inch stratum of lignite near the bottom.....	86 "
7. Good <i>lignite</i> , shown in the plate	5 "
8. About twelve strata consisting of dark and yellow lami- nated clays, loams and shaly limestone, including two beds of lignite about six inches thick.....	46 "
9. Gray sand.....	55 "
10. Five strata of laminated clay loam with sandstone con- cretions, including two thin layers of lignite	17 "
11. Quite pure <i>lignite</i>	5 "
12. Light colored silt or loam	21 "
13. Shales, dark and light, almost lignite below.....	7 "
14. Coarse sand with small concretions.....	10 "
15. Very pure <i>lignite</i>	3½"
16. Light colored clay three feet, then talus	30 "
17. Light colored silt, with some sandstone	20 "
18. Eleven strata, clays, loams, a little sandstone, and three thin layers of lignite, the lowest with large pieces of wood.....	42 "
<hr/>	
Total, about	486 feet



a.—BRICK PLANT OF C. A. MARSHALL NEAR RAPID CITY.



b.—BEDS OF FIRE CLAY SOUTHWEST OF RAPID CITY.

Between *a* and *b* in Plate 31 is a stratum of good lignite five feet thick, and below the bottom of the plate is another of similar thickness. Traces of two such beds seem not uncommon in that region. In the Slim Buttes near the North gap are three beds four to six feet thick, tilted at a considerable angle. Two or three miles southwest of that point, on the west side of the Slim Buttes, twenty-two feet of good and fair lignite are found in three beds in a vertical distance of less than fifty feet. A seven-foot bed of good lignite occurs at Riley's on the east side of Cave hills north of the cave.

Mr. Kippax, of the Surveyor General's office, has kindly submitted for my use reports of the land surveyors, who reported "coal" near Grand river. It proves to be in the area studied and reported on by the U. S. Geological Survey in 1885. The thickest bed then found was about three feet thick and quite local. Within a few hundred feet it passed into "nodules of iron carbonate," and on the other side into "brown clay."*

The area then examined covered most of the region between the Grand and the Moreau rivers between 101° and 102° 30' W. Long. As we have seen, the lignite beds are thicker and more numerous further west.

None of the lignite beds are worked, except a little for local use. They are all far from lines of easy transportation. They may in time compete in a small way with similar beds of north Dakota, which have long been mined to advantage.

PEAT.

No beds of this material have been worked in the State. Only a few localities have been reported, and none of them have been examined thoroughly. The deposits reported are on the lands of Mrs. Curtis around the head of Cottonwood creek, in T. 98 N., R. 79 W. They are said to cover 300 acres. If so, they probably owe their existence to springs near the junction of the Tertiary sands and Cretaceous clays; and probably similar deposits may be found

* Bulletin No. 21, U. S. G. S. The Lignites of the Great Sioux Reservation, p. 13.

around the heads of the southern tributaries of White river generally.

Among the few very copious perennial springs in the eastern part of the State are some believed to be fed from the great artesian supply. One of these, three miles east of Ethan, in Davison county, abounds in an extensive growth of moss and bulrushes. It is not improbable that peat may occur there in considerable quantity. At several points along the James river in Brown, Beadle, Sanborn and Hutchinson counties, and along the Missouri, are springs of some size, supplied from sand and gravel deposits of the Glacial period, but generally so hard that calcareous deposits have interfered with the formation of peat. Moreover, the occasional severe drouths and prairie fires have probably destroyed what little beginning may have been made in that direction.

NATURAL GAS.

For many years natural gas has been known to occur at several points in the State, but only quite recently has the thought gained wide credence that a valuable and extensive supply of this product lies within our borders.

Minor Areas.—There are several minor areas scattered through the James River valley, besides the main area, which, so far as has been determined, lies along the Missouri river. One of the earliest known of these, as well as one of the most important, is at Ashton, and Mr. S. W. Bowman, of that place, has recently very kindly given the following:

The gas was first discovered by John Bushell in digging a well near the center of town, at a depth of 66 feet. The gas took fire from a miner's candle he was using. He seized the rope and was drawn up as quickly as possible, but was so badly burned that he was confined to his bed for six or eight months. The gas was found in a light colored clay overlaid by blue clay.

This was in the fall of 1881. Nothing more was done till October, 1885, when a three-inch well was put down through the 66-foot flow to a stronger flow at 89 feet, which was also in a light colored clay mixed with gravel, overlaid with blue clay. The closed pressure was forty-six pounds. I immediately piped this into my hotel and used

the gas in my kitchen and office until the next March, when water broke in and gave me so much trouble that I abandoned it. During the same time Stevens & Co. heated and lighted their large general store from the same well. There appeared to be as much gas when we quit using it as when we commenced.

The same fall John Clifford, two miles and a half south of town, while putting down a two-inch well for water, found gas at a depth of 75 feet, piped it into his house, where it furnished him fuel and light until the next July. This well not being piped all the way down to the gas, water broke in and destroyed his well. Since that time nothing has been done here with the gas.

In all artesian wells that have been put down in this vicinity, gas has been found. The strongest flows are at 450 and 700 feet. The trouble with the flow at 89 feet is that from twelve to sixteen inches below the gas there is a strong flow of water which in time breaks through and destroys the gas pressure.

More than ten years ago gas was struck on the farm of Mr. Schmidt, about three miles south of Dolton, Turner county, at a depth of more than 100 feet, and it flowed for several months.

Another locality from which it has been reported at moderate depth is a few miles north of Canistota.

Mr. J. W. Parmley, of Ipswich, kindly responds to recent inquiries as follows:

Mr. Kimmitt, a well driller, informs me that ten or eleven years ago he drilled a well on Sec. 29, T. 121, R. 66, to a depth of about 320 feet, and that he struck a very good flow of gas; that it was piped into a barn and filled a burner about the size of an ordinary gasolene stove; that the family residing there cooked potatoes, etc., thereon. Mr. Steen Hagen, the owner, has never utilized it, as he has intended. It is still flowing.

In the well now being drilled on Sec. 20, T. 122, R. 69, at 1080 feet there was a small flow of water and considerable gas coming with it.

The Main Area.—The localities already mentioned are judged to be disconnected with each other, for numerous borings between them have failed to reveal any continuity. We now proceed to outline a region in which gas seems to be generally struck. Its eastern limit so far as yet determined may be inferred from the following facts:

It appears in McClure's artesian well on Antelope creek twenty miles south of Pierre and how far east is unknown.

At Blunt gas was first noticed about fifteen years ago in wells a few miles north of town, just below the glacial clays. The supply was small, but clearly inflammable. The discovery was not followed up. Recently in drilling a deep well, Mr. Peter Norbeck kindly informs me, a large supply of gas was found 860 feet down, with the first flow of water. The well was continued to 1450 feet. The main flow of water at 1300 feet had no gas.

At Pierre, though gas had been found in a few shallow wells north of the city several years before, no large supply was struck before the drilling of the well at the Indian school in 1894. In that a strong flow of gas was met with at a depth of 800 feet, "in dark gray shale." Soon after the proprietor of the Locke hotel put down a well which supplied abundant water at a temperature of 92° F. and abundance of gas, which has been utilized for heating and lighting ever since. In 1898 a company was organized to sink a well specially for gas and power. This developed two important facts. Quantities of gas were struck at 600, 1130, 1205 and 1260 feet, with different veins of water, but none with the water at 890 feet. At 1250 feet, or 188 feet above sea level, granite was struck, which showed it to be useless to go farther. Since then another well of similar dimensions has been constructed. Dr. D. W. Robinson, of that city, has estimated that these two six-inch wells furnish the city daily 80,000 cubic feet of gas. A gas holder of 45,000 cubic feet capacity is used, and considerable overflows, though it supplies fuel for a 60 H. P. engine for the pumping station, a 57 H. P. engine for a mill, and four smaller engines of 4 H. P. each, besides lighting the whole city and supplying stoves for many houses. No careful record has been kept of amounts used.

Twelve miles north of the city on the ranch of Mr. Wadleigh, which is 300 feet or so higher than Pierre, gas and water were struck at 1400 and 1567 feet. The ratio of gas to water is estimated to be 1:3, which makes over 12,000 cubic feet per day from a three-inch well. The temperature of the water is 101° F.

Two township wells in Pearl township, T. 115, R. 79,

furnish gas with water in the ratio of 1:5, but neither is supplied so copiously. They come from 1587 and 1625 feet depth and below.

Similar results were obtained from the Hallam well on Sec. 19, T. 116, R. 78, at a depth of 1595 feet.

At Cheyenne agency on the Missouri river, gas was found at a depth of 650 feet in dark gray shale. It was roughly estimated to furnish 2,400 cubic feet a day, but has not been utilized.

At Selby, also, gas was found with the water at a depth of 1880 feet, though not noticed at first. It is said by one acquainted with both that there is more than at the Locke hotel at Pierre. When lit it makes a flame about $1\frac{1}{2} \times 5$ feet, according to my informant, Mr. Fred Griffin.

It is reported that gas is also found at Edgeley, N. D. It seems quite possible that this area may connect with those about Ipswich and possibly with Edgeley.

On the other hand, no gas appears in the deep wells at Gettysburg, Potter county; Onida, Sully county; Harold, Hyde county; or Crow Creek agency, Buffalo county.

As to the western limit, no deep borings have been made further west, except a few in the vicinity of the Black Hills. Mr. Durst, of Belle Fourche, informed me that another struck gas at a depth of 440 feet, thirty-five miles east of Belle Fourche, which burned with a flame three feet high; but I have been unable to get data first-hand. He did not strike gas in a deep boring at Snoma, nor in the flowing wells around Belle Fourche.

Probable Source and Prospects.—In nearly all of the cases reported, the gas has been found in Cretaceous formations ranging from the Dakota to the Montana. The possible exceptions are the minor areas in Turner and McCook counties, where the source may be from peaty accumulations preceding, or contemporaneous with, the Glacial period, though these have not been distinctly discovered.

Moreover, the gas seems clearly to come from different levels, some above the water, which may possibly be accounted for by leakage upward from below; and also from

the same horizons as the principal flows of water. That the upper flows may not be from below, but are derived from the level where they appear seems strongly suggested, at least, by the occurrence between, at Blunt, of a water stratum showing no gas. Besides, the upper strata about Pierre seem to correspond to the exposures of sandstone about Sioux City, which are known to contain thin beds of lignite in patches. These correspond to the Dakota in the later and narrower sense. The upper deep source at Ashton would correspond to the same.

The stronger supply, which comes with the lower flows at Pierre and north, probably come from the Lakota, as the lower part of the original Dakota is now called. Although traces of coal are not reported from that level at this end of the State, it is known to abound in plant remains with some coal around the Black Hills.

Another and perhaps more probable source may be pointed out for the lowest supplies, viz: the probable beds of coal in the eastern edge of the Carboniferous, as suggested on page 110. Gas from that source may be conceived to escape from the eroded eastern edge of that formation into the lower portion of the overlapping Lakota. Moreover, this may be assisted by the flow of water eastward along the same channels.

Further north, particularly around Selby and Ipswich, gas may be derived from beds in the Montana, which in its upper part especially is known to have accumulated carbonaceous matter in some regions, foreshadowing the conditions toward the north which formed the numerous beds of lignite in the succeeding epoch of the Laramie.

No clear trace has yet been found of low anticlinal folds in the strata to concentrate the gas, though such may appear as more borings are made. If so, they may assist in foretelling where gas may be found in abundance and where not. As it is, it seems likely that gas may be counted on as appearing with the artesian water over much of the region north of White river and west of the Missouri, besides that already mentioned east of that stream.

Uses.—This gas will be of service not only as a fuel and for lights with the Wellsbach mantle, but also as a natural airlift to raise the artesian water and cause it to flow at higher levels than it would otherwise.

Tests for Natural Gas.—As the interest in the discovery of gas may awaken false hopes, a statement of how tests may be applied may be of much service. If it escapes rapidly or in a stream, touching a match to it will determine whether it is inflammable or not. If it comes in bubbles, it may be collected by filling a fruit jar or bottle with water and inverting it in a tank or dish of water and passing the bubbles into it. When enough is collected it can be easily tested as before. It is well to know that air and carbonic acid gas are found confined in the earth and escape through borings, oftentimes with high pressure. As water passes through pipes with velocity, air is often sucked in through cracks to show as bubbles in the escape pipe. This is especially liable to mislead in artesian wells.

PETROLEUM.

This product is not yet known to exist within our borders, but the excitement produced by recent discoveries elsewhere has roused new search for it. Very naturally the occurrence of gas has led to an inference that oil may be not far away.

Reports of signs of it in the extreme southeastern part of the State arose from the excessive desire of some to find it, and the common mistaking of films of iron oxide for oil scum on water in springs and wells.

Numerous inquiries have been received by the State Geologist concerning the occurrence or probability of occurrence of oil at numerous points east of the Missouri. He would take the opportunity of forestalling other similar inquiries by saying there is little or no chance of finding oil in the eastern half of the State, at least. This will become evident when we consider:—

1. That there is no chance for finding it below the surface of quartzite or granite, which is exposed or very near the surface in Minnehaha, McCook, and portions of Tur-

ner, Hanson and Davison counties, and which underlies all the rest of the eastern half at from 300 to 2,000 feet, according to the elevation of the surface and the distance from the exposures mentioned.

2. That no clear trace of it has been found in the numerous borings which have been made for artesian wells.

Again, there is no hope of finding in Dakota formation in the western half of the State, for it is permeated so completely with artesian water, which has been flowing eastward for ages, that some trace of it would have been borne eastward into the numerous wells which have been opened. If any ever existed, it has been completely washed out. The only way of avoiding this conclusion is to suppose that there may be an anticlinal, of which no evidence has been found.

The only remaining strata which can afford petroleum are the strata older than the Dakota, which are known to lie between it and the granite in the Black Hills and extending indefinitely from them in all directions. The fact that all of these slant upward toward the Hills favors the escape of the oil to the surface in that direction, if it exists anywhere in those strata. The fact that none has been found so escaping is strong presumptive evidence that none exists. The only way to avoid such a conclusion is by supposing a dome-shaped fold, or an anticlinal, which would prevent such an escape, and no trace of such a condition has been found.

It remains to consider the probability of finding such a deposit in the strata above the Dakota, in the later Cretaceous or Tertiary rocks. In favor of the possibility or even probability the following considerations are suggested by our present knowledge of the geological structure:

1. There are quantities of organic matter deposited in them, especially in the upper part of the Cretaceous.

2. The strata, being composed largely of clay, are mainly impervious and hence so far favorable for retaining any oil compounds which may have been deposited within them. On the other hand, however, there may be doubt whether sufficiently porous strata occur for conveying them



a.—LITHOGRAPHIC STONE, TEN MILES WEST OF CUSTER,
Stratum four feet thick below the star.



b.—FULLERS' EARTH NORTHEAST OF FAIRBURN.

or anticlinal folds for collecting them. There is little or no evidence of either.

3. These strata are known to contain petroleum elsewhere.

In our neighbor State, Wyoming, at New Castle, a thick lubricating oil is obtained from the Graneros shales of the Benton. (See section, p. 3.)*

So, also, the Rattlesnake oil field is supplied from the whole upper Cretaceous, including the Dakota.

The Salt Creek basin, which is quite productive, is supplied mainly from the Pierre and Fox Hill formations.†

In Colorado, also, the same formations are more or less productive.

Hence we conclude that it is not improbable that petroleum may be found in the northwestern quarter of the State, though there is as yet no distinct sign of its presence.

Tests for Petroleum.—The most decisive test is to collect it and show its inflammability. A simpler test may often, however, render such a test unnecessary. It is popularly believed that an iridescent scum on water is sign of oil; but while oil will produce a scum, several other things will also, particularly, oxide of iron, which is very apt to form in connection with organic substances. This occurs very commonly. A very simple observation will invariably detect the difference between this and oil. At ordinary temperatures the former is solid and the latter liquid; hence, if the water is stirred, the former cracks into angular fragments, while the latter streams or flows.

Mineral Waters.

The mineral waters of South Dakota are doubtless as varied as those of any other State of the Union. The wide range of geological conditions, including a nearly complete mountain unit which has been subjected to repeated disturbances, and extensive plains upon which rivers have borne the solutions from the Rocky mountains for

* Twenty-first Annual Report U. S. G. S., Part IV, p. 586. Darton.

† See Petroleum Series of Wyoming. School of Mines Bulletin, by Profs. Knight and Slosson.

ages, and underlaid with a wonderful subterranean drainage, all unite in making this a safe conclusion. Nevertheless, but one locality has become prominent as a resort and had its waters placed on the market. This is that of the well-known Hot Springs of the white man or the "Minnekahta" of the red man, who, long before the former came, prized them for their genial temperature and curative properties.

THE MAIN LOCALITY.

According to Mr. Darton, all the principal springs are connected with the Minnekahta limestone, locally known as the Purple limestone. It seems that the underlying Minnelusa sandstones have collected it from the outer slopes of the Hills to the north and west, but it overflows through the crevices and channels in the limestone which everywhere forms the inner slope of the Red valley. The reason why the waters escape more copiously and at a higher temperature at this point may be in some way connected with a sharp fold in the strata a little west of the town.

The popularity of the locality is attested by the building here of several large hotels and many minor ones, capable of accommodating more than 1200 people. The largest of these, the Evans, furnished with all modern conveniences, is a beautiful five-story structure of pink sandstone erected at a cost of \$200,000. It will accommodate 400 guests; all rooms are outside rooms. The soldiers' home of the State is located here, and there is talk of erecting a national one. Two large plunge baths, which may be used by hundreds at a time, and about half a dozen sanitariums afford abundant accommodations for all. Two railroads make the point easily accessible from all parts of the country. The excellence of the mineral waters is the main reason for all these improvements. No illustrations are presented here, for they are freely scattered in advertising circulars.*

THE SPRINGS AND WELLS.—1. *The Minnekahta Springs* are located in a side ravine a few hundred yards

* Address J. Francis, General Passenger Agent, B. & M. R. R., Omaha, or H. D. Clark, Hot Springs.

east of the railroad station. They are now covered with a bath house. As near as can be judged, they well up through a bed of travertine. These are the original springs utilized by the Indians. The temperature of the springs is 92° F.

2. *The Mammoth Spring* appears in the bed of Hot brook, where it crosses the Minnekahta limestone. It supplies the Evans plunge bath, in which the temperature is 91° F., and also the new plunge which has a temperature of 82° F. It is also used to supply the city waterworks.

3. *The Hygeia or Kidney Spring* issues from under the heavy conglomerate which caps the Pleistocene terrace of the valley opposite the Evans hotel and below the mouth of the ravine leading from the Minnekahta, suggesting a possible connection with the latter, which suggestion is strengthened by a comparison of their analyses. It enjoys a high reputation for medicinal properties. Its temperature is 83° F. The water of this spring is bottled and sold quite widely as a specific for kidney diseases, but the amount sold cannot be given.

4. *The Lakota or Indian Spring* is a small spring near the railroad bridge below the junction of Cold and Hot brooks. It is used only for drinking.

5. *The Hiawatha or Catholicon Spring* is situated about a mile southeast of those already described, on the right bank of Fall river just before it enters its canyon through the Dakota ridge. It comes from quite a different source from the others. Over it is erected a fine sanitarium capable of accommodating 100 guests. Temperature 82° F.

Siloam sanitarium close by is supplied from a well professing to have similar properties.

6. *The "Lithia Spring"* is fourteen miles south of Hot Springs. I am indebted to the courtesy of Dr. Jennings, of that place, for an analysis of it. It has not yet won much prominence. Its waters abound in magnesia.

7. *The Stewart Sanitarium* and bath-house is supplied from a well which claims to go down to the same source as the main springs.

8. *Sulphur Spring Bath-House* is supplied from a well located near the station of the F., E. & M. V. Ry. The water comes from a depth of 166 feet. No analysis has been made.

Cold spring, which does not profess to be medicinal, is at the head of running water in Cold brook, less than half a mile from Mammoth spring. It issues from the red marly sandstone a short distance from the Minnekahta limestone and has a temperature of 52.5° F.

ANALYSES.—The Survey has not had the means for analyzing the waters, nor for thoroughly investigating their curative qualities. The analyses published on the following page are judged to be reliable, because signed by disinterested and qualified chemists.

OTHER POSSIBLE LOCALITIES.

Copious springs issue from the Minnekahta limestone at many other points around the Hills. Some of these may be found having peculiar virtues.

Thermal springs are reported along the Missouri river in Charles Mix county and elsewhere. These are probably connected with oxidizing pyrites and should be investigated, without, however, very great expectations.

Along the James river at several points very copious springs exist, which come from the artesian supply.

At Wessington Springs a copious spring issues from the lower part of the Pleistocene, which is sulphurous, and at one time was something of a pleasure resort.

MINERAL PROPERTIES OF ARTESIAN AND OTHER DEEP WELLS.

It was at first planned to issue with this bulletin, or soon after, a systematic treatment of all the water resources of our State, particularly of our wonderful artesian supply, and much material has been collected, but time and lack of means have rendered it necessary to postpone such publication for some time yet. We have space for only a few general statements.

All artesian well waters contain considerable mineral

Analysis of Waters from Hot Springs and Vicinity.

CONSTITUENTS. Given in grains per gallon.	1	2	3	4	5	6	7	8
Sulphate of Sodium.....	25.620	6.440	23.2628	8.8241	127.457	4.3656	1.382	2.500
do Potassium.....	16.352	17.680	5.6272	3.3312	42.8521	42.8521	160	160
do Calcium.....	4.320	13.530	36.1125	16.2909	11.509	72.3253	16.947	27.600
do Magnesium.....	13.790	5.5887	4.1144	8.4990	9.747	10.9521	4.123	3.583
Chloride of Sodium.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
do Potassium.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
do Calcium.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
do Magnesium.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
Nitrate of Magnesium.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
do Ammonium.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
Phosphate of Calcium.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
do Magnesium.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
Carbonate of Calcium.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
do Magnesium.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
Peroxide of Iron.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
do Iron.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
Alumina.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
Silica.....	13.530	5.5887	5.5887	8.4990	1.370	3107	11.752	3.583
Inorganic and Non-volatile Organic and Volatile Total Residue.....	62.546	50.808	71.0000	49.1600	164.833	165.1676	59.250	63.874
			12.1100	8.0500				79.000
			83.1000	57.2100				

Nos. 1 and 2 are analyses of the Minnekahta spring. No. 1 by G. A. Mariner, No. 2 by Edgar Carr, both of Chicago. No. 3, the Mammoth spring, by Chas. B. Gibson, of Chicago. No. 4, the Lakota or Indian spring, by the same chemist as No. 3. No. 5, the Catholicon or Hiawatha spring, by E. C. Smith, of Beloit College, Wisconsin. No. 6, the Lithia spring fourteen miles south, made by Chas. R. Gibson. No. 7, the Hygeia or Kidney spring. No. 8, the Mammoth spring. These last two are by the State School of Mines.

matter. Those are hard where lime and magnesium salts are prominent, and those soft which abound in soda salts. Wells deriving their waters from the glacial drift deposits, whether flowing or not, in the eastern half of the State are usually quite hard. Those supplied from the upper layers of the Dakota are generally soft, both around Belle Fourche and in the eastern part of the State. Pump wells and a few flowing wells "soft as rain water" are found from Geddes in Chas. Mix county northward and through the James River valley, at least as far north as Huron. Deeper wells are generally hard, especially toward the south. Passing north from Mitchell, the lower flows, which are hard at that point, become soft one after another in quite regular descending order, so that at Redfield most are soft.

The valuable table on the following page, compiled mainly from Bulletins 41 and 49, U. S. Experiment Station, South Dakota, by Prof. Jas. H. Shepard, of Brookings, gives the analyses of several of the more prominent wells.

Numbers 1 to 20 are all from deep artesian wells from 500 to 1500 feet deep. Nos. 1 to 12 are all on and north of the latitude of Huron, and are grouped together by Shepard as first-flow wells and marked by having a larger proportion of sodium compounds, while 13 to 20 are assumed by him to be second-flow, with a larger proportion of lime and magnesia. They are all south of the latitude of Huron, except Aberdeen and Northville, which he thinks are contaminated by mixing of the flows. Later study has made it more probable that there is softer water in the same flows farther north, as already stated; also, that there are more flows than two, and, therefore, that the matter is more complicated than Professor Shepard supposed.

No. 21, by a Chicago chemist, is the only example from the first stratum below the chalk, which supplies the widely distributed soft-water pump wells. In a few cases at lower levels it gives flows. Plate 27b shows one such, while from the same hole hard water flows from a lower level. It is on the farm of John Althen northwest of Mt. Vernon.

Analyses of Some of the More Prominent Deep Wells of the State. (Parts per thousand.)

Number.	Locality.	Sodium Chloride. (NaCl)	Sodium Sulphate. (NaSO ₄)	Sodium Carbonate. (NaCO ₃)	Magnesium Sulphate. (MgSO ₄)	Magnesium Carbonate. (MgCO ₃)	Calcium Sulphate. (CaSO ₄)	Calcium Carbonate. (CaCO ₃)	Potassium Chloride. (KCl)	Silica. (SiO ₂)	Alumina.	Ferric Oxide. (Fe ₂ O ₃)
1	Pierre.....	2,8052	4550	5711	.....	0050	.....	0771	.....	0122	.....	0054
2	Hartford.....	8029	1,2265	3817	.....	0575	.....	0225	.....	0122	.....	0054
3	Miller.....	1501	2046	.....	2657	.....	1683	2125	.....	0092	.....	0290
4	Huron.....	6083	2598	6083	2661	.....	6020	1554	.....	0080	.....	0040
5	Troquois.....	2598	1,6153	2432	.....	0353	.....	0195	.....	0060	.....	0040
6	Hitchcock.....	1595	6120	.....	4383	.....	6989	1534	.....	0088	.....	0158
7	Faulton.....	6610	7890	3814	.....	0716	.....	0471	.....	0096	.....	0198
8	Redfield.....	2626	1,5701	0499	.....	0664	.....	0854	.....	0114	.....	0070
9	Doland.....	3473	1,5091	2057	.....	0512	.....	0230	.....	0104	.....	0070
10	Ipswich.....	8089	5076	7079	.....	0657	.....	0239	.....	0050	.....	0090
11	Andover.....	3308	1,6573	2476	.....	0449	.....	0248	.....	0094	.....	0088
12	Westport.....	3081	1,5031	4177	5475	0386	.....	0200	.....	0114	.....	0118
13	Yankton.....	1643	1172	.....	3160	.....	8700	1246	.....	0070	.....	0118
14	Tyndall.....	2438	1002	.....	4036	.....	1,1199	0905	.....	0076	.....	0246
15	Armour.....	2879	1186	.....	5011	.....	1,0550	1564	.....	0090	.....	0122
16	Chamberlain.....	1800	3618	.....	4735	.....	8920	1573	.....	0088	.....	0116
17	Kimball.....	1688	2211	.....	4834	.....	1,0592	1636	.....	0072	.....	0090
18	Woonsocket.....	1128	7941	.....	3701	.....	5360	1630	.....	0236	.....	0072
19	Northville.....	6396	1820	.....	3988	.....	2280	5580	.....	0368	.....	0148
20	Aberdeen.....	2381	1,6538	0108	.....	0811	.....	0879	.....	0098	.....	0094
21	Geddes (pump well).....	9224	.....	5888	.....	0174	.....	0417	0217	0091	00044	0094
22	Twin Brooks.....	0043	2037	.....	4965	.....	1183	3584	.....	0264	.....	0100
23	Reville.....	0257	0643	.....	6255	.....	3082	3655	.....	0400	.....	0906
24	Hurley.....	0117	0199	.....	5784	.....	8218	4296	.....	0248	.....	0110
25	Buchanan well.....	0684	1318	.....	4798	.....	3857	4770	.....	0324	.....	0232
26	Artesian City.....	1123	3941	.....	2687	.....	6239	1880	.....	0500	.....	0246
27	Shepard, Brookings.....	0086	1458	.....	4311	0147	.....	3427	.....	0408	.....	.....
28	Argentine.....	0473	1,3735	.....	.....	1854	3732	1142	.....	0087	.....	trace

Numbers 22 to 27 are from the sands in or below the glacial till or boulder clay. All are flowing, except the last, which is a pump well. Their waters are all hard. No. 28 is from a deep flowing well, analysis by Mr. F. J. Angier, chemist of the Burlington railroad.

The medicinal value of the waters has not been tested. Without doubt some of them, especially those of higher temperature, will be found to have considerable therapeutic value. The wells of Hughes and Sully counties have temperatures ranging from 90° F. to 101° F. and are rich in soda salts. That at Pierre may be considered typical. They generally carry much marsh gas.

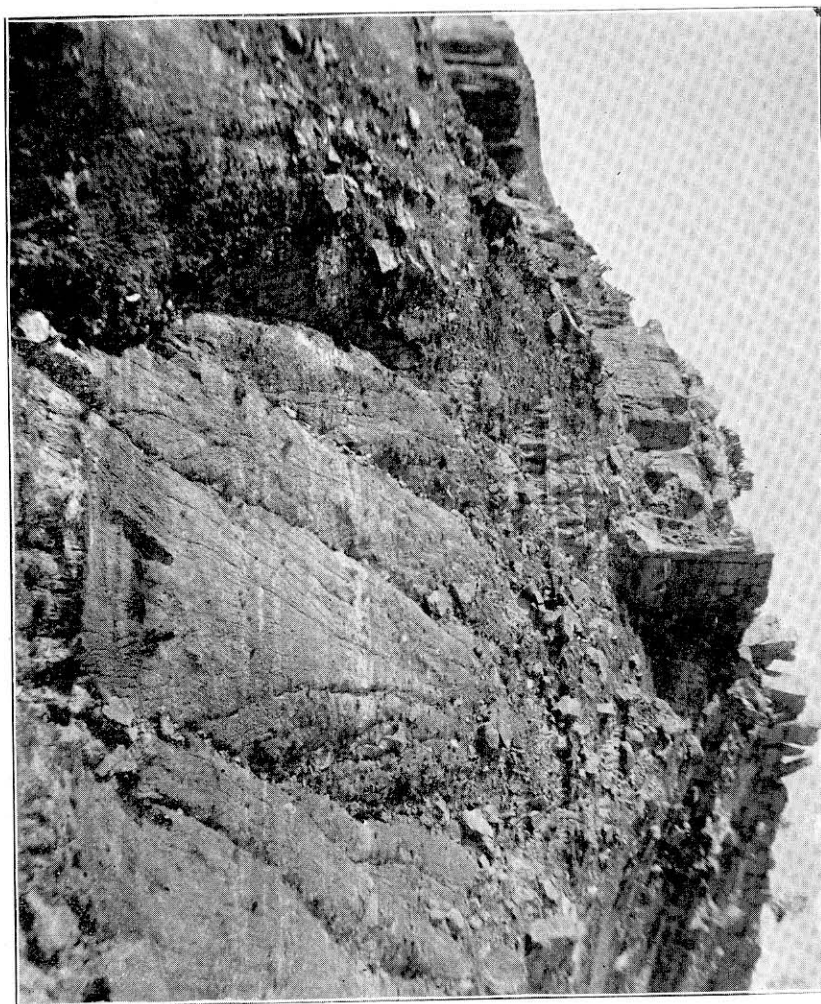
Artesian waters are free from organic matter and germs of disease, so that fevers are notably diminished by their use. Trace of lithia, which is valued as a medicine, especially for rheumatism, is found in nearly all the deep artesian waters.

From the table it will be noticed that sodium sulphate or Glauber salts, magnesium sulphate or Epsom salts, and iron salts, which are more or less used medicinally, are all found in considerable quantities in the artesian wells. In most cases they are so weak or so neutralize one another that a healthy system may drink them with impunity.

Prof. Jas. H. Shepard, in discussing the subject a few years since, expressed it well when he said:

In general it would be safe to say that the artesian waters, as a rule are tonic-laxative in their effects on the system. All artesian waters of the State carry a larger amount of salts than would be desired in first-class potable water. But it nevertheless remains a fact that in some cities these waters are used with impunity for all domestic purposes, and, in fact, no other water is used at all.

He accounts for this by supposing that as the waters carry no germs of disease, the energies of the system are not weakened at any time by such diseases as arise from organically impure water, and consequently "the system finds it less difficult to eliminate the excess of saline compounds than it would to ward off the effects of albuminous poisons and disease germs." Again, the system has a capacity of learning to thrive on that which is at first offens-



SOUTH END OF NORTH CAVE HILLS, SHOWING A 5-FOOT BED OF LIGNITE BETWEEN "a" AND "b".

ive, because it learns to eliminate any excess which might be injurious.

Concerning the laxative effects which may show themselves in early stages, he suggests that "in towns where soft artesian waters are used and injurious effects follow, "the acids of fresh fruits would certainly tend to neutralize the effects of the ant-acid salts of the waters." *

Concerning the suitability of the waters for irrigation, the same authority concludes that the hard waters are better adapted for that purpose, particularly for lands inclined to be clayey; that "if evil effects from the water be manifest, the remedial agencies of land plaster, lime and under drainage should be promptly applied." The soft waters, on the contrary, are to be used with greater caution, because rich in soda salts, which, though helpful to vegetation when diluted, are very harmful when contracted.

General Summary for 1900.

On the following page the amounts and values of different products with the names of producers are shown in tabular form. This has been obtained direct from the parties indicated. It is not unlikely that some minor plants have been overlooked. It is, therefore, not exaggerated at all, and we believe it is fairly complete, at least for a first attempt.

The adjoining table showing production by years is taken from the annual reports of the U. S. Geological Survey, with the exception of 1900, which is taken from the other table.

* South Dakota Experiment Station, Bulletin 41, p. 8.

Value of Stone Production by Years.

"Granite" .. Sandstone .. Limestone .. Gypsum	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.
	\$2,650	\$304,673 93,570 7,750	\$100,000 25,000 9,618	\$50,000 20,000	\$27,828 36,165 100 12,500	\$8,806 9,000 3,663 16,050	\$33,279 26,100 4,000 20,600	\$199,977 37,077 3,126	\$68,961 3,895 19,240	\$17,443 9,000 26,858	\$91,049 18,325 45,809	\$61,057 26,500 34,543 16,000

General Summary for 1900.

ABBREVIATIONS.—cl. Carload. c. Cord. p. Perch. t. Tons. m. Thousands. bbl. Barrels. bu. Bushels.

BUILDING STONE.

Parties and Addresses.	Product.	Amount.	Value.
Penitentiary, Sioux Falls*.....	Footing Stone.....cl	23	\$15,147
do.....	Building Stone.....cl	118	
do.....	Cut Stone.....cl	83	
do.....	Macadam.....cl	10	
Lewis & Handley, Sioux Falls...	Pav. and B'ld'g.....c	769	39,514
J. J. Nysoe, Sioux Falls.....	Rubble for B'ld'g.....c	226	1,000
Moses Blum, Sioux Falls.....	Rubble.....c	400	1,600
E. A. Erwin, Dell Rapids.....	.....	200	800
Spencer Stone Co., Spencer.....	.....	650	3,000
\$61,051			
SANDSTONE.			
W. V. Doyle, Doyle.....	Building Stone.....cl	50	\$ 1,500
Homestake Co., Lead.....	do.....p	20,000	25,000
\$26,500			
LIMESTONE.			
Geo. Schon, Spearfish.....	Building Stone.....p	400	\$ 1,200
Golden Reward, Deadwood.....	do.....p	936	561
do.....	Flux.....t	92,839	33,082
W. V. Doyle, Doyle.....	Lime.....cl	40	2,500
\$53,343			
LIME.			
Wood & Tipton, Pringle.....	Lime.....bu	10,000	\$ 3,000
Aug. Schedine, Deadwood.....	Lime.....bu	9,000	2,700
\$57,000			
GYPSUM PLASTER.			
Hot Spr. Plaster Co., Hot Springs	Hard Wall Plaster, t	3,000	\$16,000
CEMENT.			
Yankton Cement Co., Yankton...	Portland Cement, bbl	39,500	\$80,000
BRICK.			
W. C. Cone, DeSmet.....	Com. Red B'ld'g Br. m	100	\$ 700
W. R. Mason, DeSmet.....	Wall Brick.....m	156	1,248
W. G. Bower, Vermillion.....	Common Brick.....m	300	2,400
Big Stone Br. Co., Big Stone City	do.....m	1,000	6,500
Englewood Brick Co., Englewood	Building Brick.....m	500	6,000
W. E. Butler, Lead.....	do.....m	175	1,750
Brown & Robinson, Hill City....	do.....m	275	2,475
C. A. Marshall, Rapid City.....	Fire Brick.....m	150	4,500
do.....	Common Brick.....m	200	2,025
do.....	Tiles.....	2,500	500
\$28,098			

* This report is for the year ending June 30, 1900.

Index.

ALBITE.....	64, 83, 88, 102	Black Hills Development Co....	21
Algonkian.....	2, 4, 5, 11, 23	Black Hills Gold Extraction Co.	40
	59, 71, 78, 82, 88	Black Hills Placer Mining Co.	46
Alice Mica Mine.....	73	Black Hills Porcelain Clay	
Almandite.....	64	and Marble Co.....	88, 93
Alpha-Omega gold mine.....	24	Blacktail gulch.....	9, 28, 47
Amalgamating stamp mills.....	50	Blake, W. P.....	63, 64, 66, 75
American Express gold mine.....	32	Blanket formation.....	35
Amphibolites.....	3, 21, 23, 82	Blatchford, Mr.....	37
Analyses—		Blue Lead copper property.....	53, 54
Cement gold.....	27	Blue siliceous ore.....	36
Homestake gold.....	27	Bob Ingersoll mine.....	65
Fire clay.....	104	Bobtail gulch.....	26, 47
Fullers' earth.....	108	Bodener, Wm.....	108
Iron ore.....	58	Boomerang spodumene prop.....	77
Lime-siliceous ore.....	42	Bower, W. G.....	105, 130
Placer gold.....	48	Bowman, S. W.....	114
Siliceous ores.....	39	Box Elder.....	47
Spodumene.....	76	Breccias.....	11, 16
Tin ore.....	66	Brick.....	104, 106, 130
Waters.....	124, 125, 127	British Am. copper property.....	54
Wolframite.....	70	Buffalo Gap.....	10
Andalusite.....	67	Building stone.....	82
Andesite.....	84	Bullion gold mine.....	18
Ankeny, O. P.....	40	Burke Stone Co.....	97
Antimony.....	38, 77	Burlington railroad.....	10, 95, 122
Apatite.....	64	Buxton gold mine.....	36
Arrastre.....	19, 24, 40	Buxton Mining Co.....	40
Arsenopyrite.....	22, 64		
Artesian wells.....	126, 127	CALCIUM.....	38
Assay office.....	80	Caledonia.....	20
Assays of tin ores.....	66	Cambrian.....	4, 5, 11, 23, 25, 27, 28
Atlantic gold mine.....	12	.....	29, 61, 68, 69, 71, 82, 85, 90, 94
Aurum, The.....	51	Carbonate.....	50, 60, 77
Autunite.....	64	Carboniferous.....	2, 3, 5, 11, 23
		.....	59, 89, 91, 110
BALD MOUNTAIN.....	10, 29	Carlile formation.....	3
Balmoral.....	47	Carpenter, F. R.....	18, 21, 22, 50
Barite.....	38, 64, 69	.....	65, 66, 78, 92
Barrel, R. W.....	62	Cassiterite.....	49, 63-67, 75
Basic eruptions.....	4, 23	Catholicon spring.....	123
Battle creek.....	46, 47, 48	Celia mica mine.....	73
Bear gulch.....	30, 67	Cement.....	98, 101
Beryl.....	64	Cement ores.....	23, 29, 52
Benton group.....	3	Cerargyrite.....	60
Beulah shale.....	3	Cerussite.....	60
Big Bonanza gold mine.....	32	Chalkstone.....	93
Big Stone City Brick Co.....	106, 130	Chief of the Hills gold mine.....	24
Bion pyrite vein.....	16	Chilkoot gold mine.....	14
Biotite.....	64	Chilkoot district.....	15
Bismuth.....	64, 77	Chloridizing plant.....	60
Black Hills Copper Co.....	53, 54	Chlorination process.....	40, 51

Cinnabar	78
Clays	98, 101, 109
Brick	104, 105
China	102
Fire	102, 104
Cleopatra gold mine	31, 33, 36
	42, 44
Climax mica mine	72, 74
Coal	110
Columbite	49, 64, 66
Cone, W. E.	106
Conglomerate ores	9, 11, 23-29
Corundum	64
Crystals, size of	65, 75
Copper	11, 53-56
Copper Castle property	54
Copper Cliff property	54
Copper Gance property	54
Copper Reef property	54
Cretaceous	2, 3, 5, 85, 89
	98, 101, 106, 109, 110
Cross, Fred J.	63
Crown mica mine	73
Crown hill	10, 29, 31
Cupro-cassiterite	64, 65
Custer	6, 7, 12, 58, 59, 72, 74, 75, 77
Custer county	12, 16, 58, 59, 73
Custer, Gen., expedition of	6, 7
Cyaniding	57
Cyanide lixiviation	40
Cyanide plants	20, 22, 50, 51
DACITES	3
Dacy drill hole	32
Dacy flat	41, 42, 45
Dacy shaft	32
Dacy vertical	43
Dakota formation	3, 94, 96
	98, 104, 110
Darrow & Mowatt	95
Darton, N. H.	34, 85, 90, 92
	107, 108, 110, 122
Davier mine	78
Deadwood, city of	4, 10, 19, 23
	40, 50, 54, 60
Deadwood formation	3, 25
Deadwood gulch	9, 24, 26, 28, 68
Deadwood mill	21
Deadwood placers	23, 28, 47
Deadwood & Delaware smelter	40, 50
Deadwood Stand. Mining Co.	43
Decorah gold mine	31, 32
Delaware shaft	32
Depth of shafts	14, 21, 33
Devereux, W. B.	26, 27
Diabase	82
Dikes	11, 16, 30, 63, 73
Dioritic rocks	16
Discovery claim	9, 48
Discovery of gold	7
Dolomite	88, 91
Doyle vertical	43
Doyle, W. V.	91, 130
Drainage	4
Drake Polishing Co.	87
Dry diggings	46
Ducktown copper deposits	55
Durango gold mine	68, 72
Durst, F. A.	117
EARLY PROSPECTING	7, 8
Elephas primigenius	50
Elk creek	47, 54
Elk gulch	62
Elkhorn prairie	57
Emma mica mine	73
Empire gold mine	40
Englewood limestone	3
Enos, Mr.	19
Epidote	64
Erwin, E. A.	87
Estrella del Norte Co	46
Etta tin mine	63, 64, 71, 75, 76, 83
Eureka mica mine	73
Evans quarry	97
Exploratory work, method of	36
FATHER DESMET MILL	21
Faulting in ore bodies	33
F. E. & M. V. R. R.	10
Feldspar	102
Fire brick	103, 130
Fire clay	102, 104
Fissure veins	11, 13
Flintermann, Prof.	108
Fluorite	38
Fluxes	16, 57
Folger gold mine	40
Fossil placers	26
Fossils in placer deposits	49
Fox Hill formation	3, 98
Free milling ores	40
Fregert, H. R.	106
French creek	6, 8, 12, 47
Fuson formation	3, 103, 104
Fullers' earth	107, 108
GALENA DISTRICT	16, 29, 35, 60, 61
Galena, mineral	14, 60, 64
Galena, town of	10, 29, 60
Gardner, Chase & Co.	24
Garnets	49
Gas	114
Prospects	117
Tests	119
Gashweiler, Gen.	63
Gems	64

Geological formations	1, 2, 81
Generalized section	3
Giant claim	19
Gilmore pyrite vein	16
Glacial deposits	89
Glass sand	109
Gold	1, 6, 7, 10, 53, 61
Gold, classification of ores	11
Gold, free in Cambrian	28
Golden Crown mine	68
Golden Reward Co.	35, 37, 91
Golden Reward chlorination plant	40
Golden Reward smelter	16, 51, 101
Golden Star claim	19
Golden Star mill	20
Golden Terra mill	20
Gold hill	25
Gossan	54, 55, 58
Grand Junction gold mine	12
Grand View claim	77
Graneros shale	3
Granites	2, 5, 16, 63, 82, 83, 88, 130
Granite range	15
Graphite	11, 64, 72
Gravel	109
Greenhorn limestone	3
Green mountain	31, 40
Grindstones	97
Gripthite	64
Grizzly Bear gold mine	12
Grizzly gulch	46
Grossularite	64
Gustavus gold property	40
Gypsum	3, 5, 38, 99
HAGGIN, J. B.	19
Harney Hydraulic Co.	46
Harney granite range	2
Harney Peak	2, 8, 49
Harney Peak Tin Co.	63, 66
Harrison gold mine	68, 72
Hayden, Dr. F. V.	96
Headden, W. P.	63, 65, 92
Hearst, Senator	19
Heinault, D.	108
Hematite	37, 57, 59, 61
Heterosite	64
Hiawatha Spring	123, 125
Hidden Fortune Co.	21
Hidden Fortune mine	29, 68
Hidden Treasure mine	24
Highland mine	19
Highland mill	21
Hill City	11, 12, 54, 77
Hillebrand, W. E.	70
Historical review	6-11
Hoffman, H. O.	66
Hogback ridges	2
Holmes, J. A.	74
Holy Fright copper property	54
Holy Terror mine	12, 14, 15
Homestake belt	10, 18, 21, 25, 52
Homestake Co.	10
Homestake open cuts	21
Homestake lode	71
Homestake mills	21, 50
Homestake mine	18-20, 27, 52, 69
Homestake tailings	22, 51
Honestone	96
Hoodoo mine	17
Hornblende district	18
Hot Springs	122
Hot Springs Plaster Co.	99
Huronian	82, 85
Hydliff, M. R.	49, 67
Hydraulic mining	46
Hygeia spring	123, 125
IGNEOUS ROCKS	29
Ilmenite	64
Impregnated zones	18
Indians	7, 8
Indian Affairs, Commissioner	.7
Indian depredations	9
Indispensable claim	40
Ingersoll mine	65, 76
Iron	11, 37, 57-59
Iron carbonate	61
Iron Hill mine	41, 60, 61
Iron mountain	58
Irving, J. D.	30, 37, 38, 39
	42, 69, 70, 84
JAMESONITE	61, 77
Jasper ore	58, 61
Jenney, W. P.	7, 8, 13, 16, 47
Jensen, Prof. H. W.	92
Joint planes	44
Jurassic	3, 5, 94, 95
KAOLIN	102
Kellogg, L. D.	19
Keystone	11, 14, 18, 46, 58, 73, 77
Keystone gold mine	14
Keystone mica mine	73
Kidney siliceous ore	37
Kidney spring	123, 125
Kildonan Milling Co.	40
Kiln roasting	40
King Solomon gold mine	12
Kippax, Mr.	113
LACCOLITES	30
Lakota formation	3, 85, 96
	110, 111
Lakota spring	123, 125
Lame Johnny creek	85

Laramie formation 3, 94, 98
 104, 106
 Lardner, William 47
 Last Chance mica mine 73
 Laurentian 82
 Lawrence county 10, 12, 13
 Lead City 10, 19, 20, 50, 67, 69
 Lead-silver deposits 59-67
 Lepidolite 64
 Leucopyrite 64
 Liebnerite 64
 Lignite 111, 112
 Lime 91, 99, 130
 Lime siliceous ores 10, 40-44
 Limestone 2, 82, 93
 Limonite 37, 49, 58, 61
 Lithia spring 123, 125
 Lithium salts 77
 Little Bud vertical 43
 Little Rapid creek 48
 Loess 106
 Lost Bonanza mica mine, 72, 73, 74
 Loup Fork formation 82, 98
 Lowe & Handley 87, 130
 Lower contact 31
 Lower quartzite 61
 Ludlow, William 6
 Lundteigen, Andreas 100

MAGNESIUM 38
 Mammoth spring 123, 125
 Manganese 11, 59
 Marble 88
 Marshall, C. A. 103, 105
 Mason, W. R. 106
 Mastiff copper property 54
 May Flower gold property 12
 M'Gillycuddy, Dr. 76
 McKay, W. T. 6
 McMackin mica mine. 72, 73, 74
 McMasters, Samuel 20
 Metallurgical processes 52
 Mica 11, 63, 72-74
 Millard mica mine 73
 Milling character of gold ores, 50
 Milling of tin ores 66
 Mineral associates 37, 64, 75
 Mineral fuels 110
 Mineral paint works 59, 72
 Mineralized zones 11
 Miners' wax 37
 Mineral waters 121, 124
 Minnekahta limestone 3, 91, 92
 93, 122
 Minnekahta spring 122, 125
 Minnelusa formation 3, 59, 94
 Minnewaste limestone 3
 Mint, report of director of 62
 Miocene 82, 85, 94

Miscellaneous minerals 77, 78
 Monarch mica mine 73
 Montana gold property 12
 Montana formation 100
 Muckley, John 95
 Muscovite 64

NELLIE MICA MINE 73
 Newark mine 14
 Newton, Henry 6, 7, 8, 13, 57, 58
 Newton - Jenney, survey 7
 New York mica mine 72, 73, 74
 Nickel 55
 Nigger Hill. 46, 48, 49, 63, 67, 69, 71
 Niobrara formation 3
 Norbeck, Peter 116
 North Cave Hills 112
 Northern connected district 29
 North Star gold mine 29
 Nuggets 53
 Nysoe, J. J. 87, 130

OCHRE 58, 59
 O'Harra, Prof. C. C. 81, 103
 Old Abe gold property 19
 Old Bill gold property 12
 Old Charlie gold property 12
 Olive gold property 40
 Olivenite 64
 Opeche formation 3
 Orthoclase 64
 Output of Gold 52
 do Copper 56
 do Iron 57, 59
 do Manganese 59
 do Lead 62
 do Silver 61
 do Tin 66
 do Tungsten 67
 do Graphite 72
 do Mica 72, 73
 do Spodumene 76, 77
 Output, summary of 79

PACTOLA 46, 54, 78
 Pahasappa limestone 3, 90
 Palmer copper property 54
 Palmer Gulch mine 76
 Palmister, M. 108
 Pan-amalgamation 40
 Parmley, J. W. 115
 Pearce, Richard 38, 62
 Pearson, J. B. 19
 Peat 113
 Peerless mica mine 73
 Pegmatite 63, 69, 73, 74
 Pennington county 12, 16, 18
 Permian 53, 58, 73, 74
 3, 5

Perseverance gold mine 40
 Petalite 64
 Petroleum 119
 Petroleum tests 121
 Phonolite 3, 29, 30, 43
 Pierre shale 3, 104
 Pilgrim gold property 40
 Pinney, Milton E. 24
 Placers 9, 11, 26, 28, 45-50, 52
 Plaster 99
 Platinum 49
 Plattner process 40
 Pleistocene 4, 11, 82, 104
 Poisoned Ox copper prop. 52, 78
 Porcelain clay 102
 Porphyry 3, 16, 21, 61, 82, 84
 Portland 10, 29, 31, 35, 37, 39, 60, 78
 Portland cement 100
 Portland Mining Co 39
 Potato creek 47, 49
 Potsdam 25
 Potters' clay 104
 Pumice 109
 Purple limestone 91
 Pyrrhotite 21, 78
 Pyrite 14, 15, 16, 17, 21, 39
 Pyrolusite 59

QUARTZITE 84, 85
 Quartzite, sinking to 36
 Quartz porphyry 29-30
 Quartz veins 4, 11, 15

**RACINE MINING AND MILL-
 ING CO** 19
 Ragged Top 30, 31, 41, 42, 45
 Railroads 1, 10-11, 80
 Rainfall 4
 Ramer, Supt. M. M. 83
 Rapid City 4, 50, 78
 Rapid creek 8, 53, 57
 Rare minerals 78
 Red beds 5
 Red Canyon creek 60
 Red siliceous ores 37
 Reddy gold mine 68
 Refractory ores 14, 29, 50
 Reimbold & Co. 76
 Reitz, O. A. 68
 Resume of mineral production, 78
 Reynolds, Joseph 12
 Reynolds copper property 54
 Rhyolite 84
 Riederer, E. J. 108
 Rio Tinto copper property 54
 Riotte, E. N. 66
 Robinson, Dr. D. W. 116
 Rochford 12, 18, 53, 59, 72, 77
 Rockerville 25, 29, 45, 46

Rolker, C. M. 66
 Ross, H. N. 6
 Ruby basin. 10, 29, 31, 32, 36, 37, 51
 Rutile 64

SAND 109
 Sandstone 94
 Satin spar 100
 Schedine, August 91, 130
 Scheelite 64, 69
 Schon, George 92, 130
 Scorodite 64
 Scott, Samuel 58, 75
 Seim pyrite mine 16
 Serpentine 88
 Sheeptail gulch 29, 31
 Shepard, Prof. James H. 126, 128
 Sheridan 46, 48, 53, 54
 Siderite 14
 Siliceous gold ores 29, 44
 Silurian 5, 89
 Silver 1, 27, 37, 59, 62
 Silver Ridge property 41
 Simmons, A. J. 63
 Sioux Falls 87
 Sioux Falls "granite" 83, 86, 130
 Sioux quartzite 86
 Slag cement 101
 Slagle, Pres. R. A. 104
 Slate breccias 16
 Slavonian pyrite mine 16
 Sluicing 45, 46
 Smelter 16, 22, 51, 57, 60
 Smith, A. H. 102
 Smith, A. J. 40
 Smith, F. C. 14, 29, 37, 38, 40, 42
 Spearfish formation 3
 Spearfish Gold Mining Co. 43
 Sphalerite 14
 Spheue 64
 Spinel 64
 Spodumene 64, 75-77
 Spokane mine 61
 Stamp mills 19, 20, 24, 50
 Standby mine 18
 Stannite 64
 State penitentiary 87, 130
 Stenger, Geo. 92
 Sterner vertical 43
 Stewart sanitarium 123
 Stibnite 38, 69
 Stockade, the 7
 Stream tin 65, 67
 Strength of building stone
 87, 95, 97
 Stucco 99
 Sugar Loaf hill 30
 Sugar Loaf laccolite 32
 Sula mine 68

Sulphide enrichments.....	55	Uncle Sam mine.....	12
Sulphur	37	Union Hill mine.....	17
Sulphur Springs bath house.....	124	Union shaft	32
Summary	129	Unkpapa sandstone..	3, 95, 103, 109
Sundance formation	3	Upper contact.....	31
Sundance gold mine	32	Uranium	78
Sunday Fraction mine	77	U. S. Geological Survey	3, 80
T AILINGS	22, 50	V AN HISE, C. R.	13
Tallent, Annie D.....	12	Veins.....	11-17
Tantalite	49, 64, 66	Verticals	11, 33, 41, 43
Telegraph group.....	77	Vigilante copper property.....	54
Tellurium	38	Vincent, C. M.	66
Terraville.....	20	Vogesites	3
Terry	32, 33, 36, 38	Volcanic ash	108
Tertiary.....	3, 4, 89, 98, 104	Vosburg, Theodore	62
Tests.—Gas	119	W ARREN MICA MINE	73
Petroleum	121	Wasp No. 2 mine.....	69
Stone	87, 95, 97	Weed, W. H.....	55, 57
Tetradymite	14	Welcome Mining Co.....	40
Thoen, L. E.....	97, 130	<i>Wells</i> .—Artesian	124, 127
Thomas, Capt.....	66	Soft water.....	126
Timber.....	80	Pump	126
Tin	62-67	Wessington Springs	124
Tin Mountain vein.....	77	Western Portland Cement Co.....	101, 130
Tonalite	3	West Virginia claim	60
Topography	2	White River formation..	82, 98, 107
Tornado mine	35	White Spar mica mine.....	73, 74
Tornado shaft.....	32, 36	Whitewood creek	45, 47, 50, 68
Tourmaline.....	64	Windy flats	54
Trachyte.....	84	Window Light mica mine.....	73
Treatment, methods of.....	50	Wolframite	64, 68-72
Triassic.....	2, 3, 5	Wood & Tipton.....	91, 130
Triphyllite.....	64	Wood mine	76
Triplite	64	"Worm-eaten" sandstone.....	31
Trojan mine	40	Y ELLOW CREEK....	29, 31, 44, 68, 73
Truax copper property.....	54	Z IRCON.....	64
Tungsten	67-72		
Two Strike mine.....	69, 70		
U LKE, TITUS	65		
Ulster mine.....	42		