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COLORADO STATE SCHOOL OF MINES

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ANNUAL REPORT

— OF —

Field Work and Analyses.



GEOLOGY OF

COLORADO COAL DEPOSITS.

— BY —

PROF. ARTHUR LAKES,

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1889.



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DENVER, COLO.:

NEWS PRINTING COMPANY.

1889.

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# State School of Mines

OF COLORADO.

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# Colorado State School of Mines.

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STATE SCHOOL OF MINES, }  
GOLDEN, Oct. 31, 1889. }

*Dr. F. Steinhauer,*  
*President of Board of Trustees:*

DEAR SIR:—I transmit herewith the report, by Professor Arthur Lakes, on the Geology of Colorado Coal Deposits, which forms the report for the year 1889 of the State School of Mines.

Respectfully yours,

REGIS CHAUVENET,  
*President of Faculty.*







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## PREFACE.

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This work is a sequel to that on the "Geology of Colorado ore deposits" published a year ago by the writer, under the auspices of the School of Mines. It is written somewhat in the same strain, with a view to meeting the needs of the general public, and the ordinary coal miner.

A great deal has been published already in past years by the official Government Geological Surveys, and by other parties, on the coal fields of Colorado, but the rapid development of the State, especially of late, by the incoming of new or extended railroad lines, has opened up so many new coal districts, as well as greatly enlarged the number of mines and developments in older fields, that there is ample scope for many fresh reports. The field, too, is a very large one and exceedingly varied, both in its geological and economical characters. The coal fields are often situated in very picturesque regions, some of them being singularly interesting in geological character. While we have made these fields, their practical, economical and geological features, the leading topic of this work, we have digressed occasionally to call attention to some striking geological phenomena in the vicinity of the coal, though not directly connected with it, so that the traveler or coal miner may, if he wishes, form some idea of the structure of the country passed through on his way to the coal mines, or of what is to be seen of special interest within easy reach of the mining camp.

The illustrations accompanying this work were engraved by the American Bank Note Company of New York, from sketches made in the field by the writer. They will give an idea of the general appearance of the coal fields, and of the location of the mines, while the geological sections accompanying the surface sketches will show the number, thickness and relation of the different coal seams as revealed by underground workings, or by



natural outcrops. The general sections of the surrounding region show where the coal comes in among the various groups of strata successively revealed by upheaval along the flanks of our mountain ranges.

As regards unavoidable scientific terms, such as names of geological periods, etc., we may refer the reader to the introduction to our work on the "Geology of Colorado Ore Deposits," where a brief explanation is given of some of these terms, or else to some elementary work on geology, such as those of Professors Shaler, Dana, or Le Conte.

The first chapter is devoted to the not unfrequently asked question, "What is coal?" We have endeavored to give a brief sketch of its natural history, and to point out some of its characteristics and modes of occurrence in Colorado, as a preliminary to the more detailed accounts in succeeding chapters.

To describe minutely and accurately *all* the coal fields of Colorado would demand much greater space than that allotted to this work. We have confined ourselves to such districts as are actually being developed, and are situated along, or within easy distance of the lines of railroad, for a coal mine without a railroad near it is only of prospective value. There are large areas of very valuable coal outside of the railroad limits, which we did not visit this year, such as those lying along the Grand River between New Castle and Grand Junction, the White River District, the Middle and North Park Districts; also, a great deal of the Gunnison District, down Anthracite Creek, where extensive coal and anthracite deposits are known to exist; also, part of Southwestern Colorado, along the Montezuma valley, and a great area now covered by the Ute reservation. All these districts are at present outside of railroad limits, and come under the class of undeveloped coal fields of the future, which may form the subject of a future report, though, with the rapid strides that railroads are making, it seems likely that many of these will soon be enrolled under the class of developed and producing fields. We have given but a passing notice to old and well established mines, (about some of which we have written in former reports) concentrating our attention mainly on young and new mines, or those in newly opened districts, which will show the public



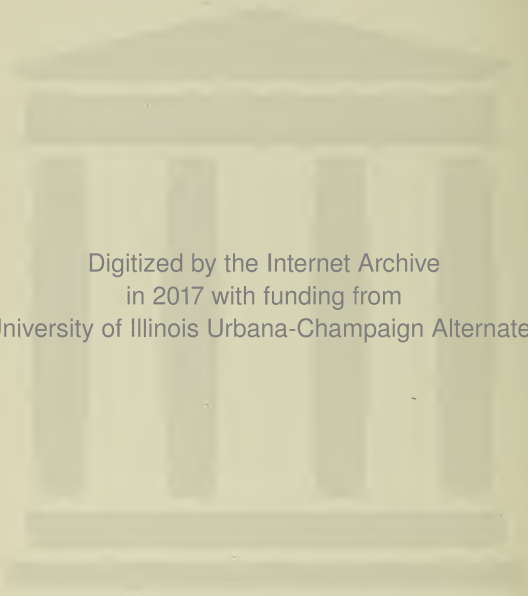
the rapid progress being made in our coal mining industry, and the great extent and value of our available coal fields. We have taken some pains to call attention not only to their great resources, but also to the excellent quality of our coal, points which we think have not been sufficiently recognized in the past, since, while people generally recognize Colorado as a leading precious metal producer, they are slow to admit it as a leading coal producing state also.

In the appendix at the end of this work is an epitome of the statistical report of the State Inspector of coal mines, Hon. John McNeil, to whose valuable publications we refer the reader for matters of a statistical character.

The analyses accompanying this work were chiefly made by Prof. Geo. C. Tilden, of the School of Mines, who accompanied the writer on some of his trips, taking the samples personally. Messrs. van Dyke, Thies, Johnson, Camp, and Wertheim, students of the school, accompanied us at different times, and rendered valuable assistance. Our thanks are due to the superintendents of the various coal mines, who gave us all possible help in our examinations, and also to the Rio Grande and Midland Railways, for assistance over their lines, recognizing, as they must, that this work is for no private interest, but for the benefit of Colorado generally, perhaps especially for that of the railroad companies.

STATE SCHOOL OF MINES,  
Golden, August, 1889.





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## CHAPTER I.

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# Natural History of Coal.







## Chapter I.

### NATURAL HISTORY OF COAL.

"What is coal?" is a question that doubtless has often occurred to the thoughtful miner, who has worked perhaps all his life in coal mines, in England, Pennsylvania or Colorado, and is practically familiar with the substance in nearly all its known forms and with nearly every condition under which it is found. The same question may also have entered the mind of the housewife, who is familiar with the stove or coal-bin, and recognizes that for household purposes some coal is much better than others.

Occasionally the miner comes across a hard round cylinder of coal or "bone" in his mine which suggests a resemblance to the trunk of a tree, and if an observing man, in first opening the seam, he will frequently have noticed in the shale and sandstone above it, impressions of leaves, and in Colorado even of palm leaves and ferns, and in the underclay beneath every seam a great number of what look like rootlets. Perhaps his suspicion that the cylinder was once a tree-trunk may be confirmed by finding that it passes down through the coal seam and actually sends off roots into the underclay, the idea thus dawning upon him that somehow coal is connected with ancient relics of vegetation. Forests and plants have lived and died for ages upon this world; what became of the dead forests? Perhaps here in this coal seam are some of their remains in a different form, sealed under tons of rock. The underclay was the soil upon which the trees grew; the coal seam is the leaf mould, dead branches and trunks, accumulated for ages around the stumps, covered up by sand and pebbles, till by pressure, moisture, heat and chemical action they are reduced to the hard mineral substance called coal.

Not far from the coal mine is a swamp which they are trying to drain by cutting a deep trench. The surface of the marsh is



covered with thick moss and sedges, and yields as we walk over it, like an india-rubber sheet. In places towards the center of the marsh is a pond of clear water, and it is evident that the whole swamp is underlaid by a stratum of water or ooze. Where they are cutting the trench we see the moss, green and living, on top of a dead fibrous mass of the same material, and below that an impalpable black mud, evidently composed of the same, only older material, reduced by water and pressure to a black vegetable pulp called peat. This rests upon a thin layer of clay, and that again upon a bed of pebbles, sand or even hard rock. The marsh is deepest towards the center, like a basin, and thins out along the edges; the peat also is thickest towards the center. Scattered over the marsh, imbedded in the moss and mud, are trunks and stools of trees which once grew there, till they rotted and fell, and in the section shown by the ditch their roots may be seen running down into the clay seam. Dead leaves and branches are also found mixed up in the peat, which are turning black and passing into that substance. A freshet from the hills, like one of our Colorado cloudbursts, has lately rushed down into the swamp and covered quite a large part of it with a layer of sand and pebbles, mingled with tree-trunks. The winds, too, keep blowing the autumnal leaves from the surrounding forest into the swamp. Occasionally we come upon the bones of some animal, a cow or deer, which was mired, or whose carcass was carried in by the freshet; for a marsh is a general dumping-place of all the rubbish brought down from the higher country. The marsh throws light on our coal seams. The peat which burns dull when dried is very like some of our poorest class of coal called "brown lignite;" and if these freshets keep on at intervals for many years and cover up the old swamp with a great thickness of sand and pebbles, the peat will turn into brown lignite. If the accumulation goes on to such a degree that a thickness of some hundreds of feet is formed, the pressure being assisted by chemical action and a certain amount of heat,\* the coal will become more compact and turn into bituminous or ordinary coal.

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\* Increasing under great thickness of rock at the rate of one degree for every fifty feet, as many a miner who has worked in very deep collieries knows.



Now should some convulsion of nature occur, and all the strata with their included coal seam be crumpled up into a mountain mass, the heat produced by this movement, together with that from lava or porphyry, which often issues in connection with such movements, might further change the coal into that hard substance called "anthracite" by a slow stewing process, by which certain volatile elements of the common coal would be driven out, leaving almost pure carbon behind. Sometimes, if the heat is very great, such as that caused by the intrusion of a lava dyke, the anthracite is further changed into the substance called "graphite" or "plumbago," which we use for lead pencils, and which, singularly enough, though a pure carbon, produced by the action of heat itself, burns only with difficulty, but is better than fire-brick for resisting heat.

The miner in Colorado will recall mines in his experience, such as in the Trinidad region, where coal has been thus changed to a hard natural coke, or to graphite, by a dyke of lava crossing the seam; the dyke he will remember to his cost, from its extreme hardness. If he has worked about Crested Butte, he will have noticed how near the great dykes and mountains of porphyry came to the coal seams, and how the coal is there in some localities anthracite, as also on Rock Creek in the same region, where huge masses of strata are overturned, folded and crumpled up like sheets of paper, while in the more level portion of the Gunnison district the coal is only common bituminous. On reflection, he will also see that the coking coal area, as at Trinidad or Crested Butte, is always within a moderate distance of some lava-capped or volcanic mountains, or where moderate overturning and uptilting have taken place, and he concludes with reason that many of the varieties of coal, such as coking coal or anthracite, are due to nothing peculiar in the coal itself, but to the influence of these volcanic agencies and to greater or less heat or pressure.

So much for a single coal seam, but the miner often finds three or four or even a dozen seams of varying thickness, one above another, separated by belts of sandstone and shale, with the same phenomena repeated in each. Now supposing that the sand brought in by the freshet upon our marsh, were again



covered by vegetation, and again became a marsh, and was covered likewise by freshet sand, we should then have two coal seams, and if this process were repeated again and again, a great number of seams would be so formed, but it is obvious that in time we should completely fill up the natural depression or basin of the marsh, and it would form dry land, in which coal could not form well for lack of moisture. It has been found that areas where great thickness of sediments are being laid down, gradually sink, which sinking, if kept up, will allow any number of different beds, and any amount of thickness to accumulate, and yet keep the surface of the marsh or lake near water level, or in shallow water. Thus large deltas, like those of the Mississippi and of the Nile, are found to be gradually sinking, and borings in them show that this has been in progress for an enormous length of time, as one forest bed after another has been found, separated by intervals of sandstone, just as in our coal beds. Gradual sinking and elevation of land are found by careful measurements to be going on all the world over, especially along the coasts of our continents, where the greatest amount of sediment is being accumulated in the sea, washed down from the land by rivers.

The writer saw in the bay of Torquay in Devonshire, (England), a peat-bed uncovered at low tide, which extends from the neighboring marshes and dry land down under the sands, below the deep waters of the bay. On land the green mossy turf is growing, but when traced down to the shore it becomes a black peat-mud, covered by the shells and sands of the beach, and finally lost beneath the waves. On the coast of Guernsey also, at a very low tide, may be seen a peat forest exposed on the beach and dug up for fuel, acorns and fragments of oak branches being easily distinguished in the blackened peat. As these trees and mosses once grew on land, it is evident that the area must have subsided. Now in these two cases of subsidence, if the buried areas were again uplifted into land, the sands having consolidated into sandstone, and the peat into coal, we should find the sandstone, overlying the beds of coal, full of fossil sea shells, as are the rocks in some cases, above the coal beds of Pennsylvania, but if the same process were carried on, in the bed of a great *inland*



lake or marsh, we should find sandstone, with occasional traces of land vegetation, and a few fresh water shells overlying the coal, as in some cases in Colorado. If, however, the marsh, as is often the case, were along the sea coast, as a delta, or bordering swamp-land, as in Florida, we might expect to find some evidences of salt-water mixed with the fresh, and brackish shells abounding. Such is in fact the case in a few instances in Colorado, as in the Newcastle, Durango and Marshall mines.

Sometimes the prospector, after following a coal seam of a certain thickness for many miles, finds it split up into two or more beds by a thick parting of shale or sandstone, returning to its original size after some miles more. In this case, as at Torquay, we may suppose that while the peat was forming, one part of the marsh sank much more than the other, the sunken portion would thus be covered with a thick deposit from the waters, and it might be a long time before the bed of the lake was built up by sediment to the former level of the marsh, and continued making peat of the same thickness as before. The small thin partings of shale so commonly found in coal seams may result from subsidence, or more probably, from the periodical discharge of sand-laden streams into the marsh, while the peat was in process of formation. It is also not uncommon for a number of seams, separated by comparatively thick partings, to unite after a certain distance in one great "mammoth" seam, as at Durango, by the gradually thinning out of the partings; they are, however, generally still to be detected in a great seam, though very thin, and for this reason it is unusual for the coal in a mammoth seam to be as pure and as free from "bone" or slate as in a small individual seam. Coal seams again will begin small and gradually thicken towards a given center, from which they will again begin to thin out, as in the case of our peat-swamp, and for the reasons already explained, so there is generally a thick portion and a thinner margin around our coal fields. A vertical or uptilted coal seam, if found thin near the surface, is not likely to grow rapidly thicker within the depth of the few hundred feet to which a shaft can go, a consideration of which fact would prevent a good deal of useless prospecting on thinly outcropping seams. Some local compression or faulting near the surface, however, may have



pinched the seam to a minimum thickness, as in the case of one of the Marion mines, while further in, the seam may widen to its true dimensions. Among the disturbed and faulted strata, such pinches and "rolls" are found in almost every mine, and were caused, not so much by irregularities in the original deposition of the peat in the bed of the marsh, as by subsequent movements of the strata. It is rarely safe, however, to go to any great depth on a seam outcropping thinly on the surface in hope of its growing thicker; we have seen many such openings made on the merest traces of coal, and much labor lost.

Considering that the low lying marshes are subject so frequently to inundations from streams carrying silt, mud, and gravel, it is remarkable to find the coal seams with comparatively so little admixture of shale or other impurities, still more so, when we find an enormous seam like that of Newcastle, 45 feet thick, with but trifling clay partings. But if we examine some of our great swamps, like those of Florida, we shall find that the center of the swamp is surrounded by thick forests and undergrowth, and frequently there is a lake of perfectly clear water in the middle, into which no sediment or sand finds its way, the bottom being wholly formed of pure peat and decaying leaves. The reason of this is, that the waters of the river at their freshets, in passing through this network of foliage, leave all their impurities attached to the outer circle of vegetation, and enter the marsh filtered as through a sieve, perfectly clear. In such places the coal might be both thick and pure.

Under the microscope, coal shows a black, hard, shining mass of vegetable substance, and no matter how compact or even anthracitic the coal may appear to the eye, the microscope will generally detect vegetable tissues in it, and the peculiar patterns of wood-cells found in the cross sections of trees and plants. In the case of peat and lignite, the woody-fibre and remains of plants, are obvious, even to the eye. Some of the coals of England show small microscopic discs in them, which are considered to be the germ cases, or pollen, of gigantic club-mosses, which must have shed it like snow, since thick beds of coal are formed almost entirely of these embryonic seeds. Doubtless microscopic sections of our Colorado coals, would detect the remains of many of



the trees, leaves and plants which we find fossilized in the rocks adjacent to the coal seam. Coal breaks in two ways, one in a plane parallel to its lamination or bedding plane, the other at right angles to it, producing what is called "end and face" structure. Between the laminae, the microscope detects a sooty substance called mineral charcoal, made of stems of leaves, that perished on the ground, by exposure to the air, and were not consolidated into coal.

Coal, as we have said, ranges through peat, which burns slowly and without flame; brown lignite, which carries a larger per cent of water, and only a moderate per cent of fixed carbon, and burns with a little more flame; bituminous coal, which is soft, melts in the fire, burns with a long flame, and has a higher per cent of carbon; anthracite which is hard, brittle and shining, burning with almost no flame, being nearly pure carbon, finally reaching the form of graphite which is practically pure carbon. Cannel-coal is a variety of bituminous coal and appears to have been formed of the finest impalpable peat mud, at the bottom of the marsh, burns with a bright flame like a candle, is of a dull lustre and capable of being polished. Little if any of this variety is yet known in Colorado.

The vegetable origin of coal is apparent from what we have said, but some of the chemical transformations of the process need explanation.

Various gases, such as oxygen, hydrogen, and carbon dioxide are elements of either air or water. The leaves of plants absorb carbon from the carbon dioxide of the atmosphere, and let the oxygen go free.

The soil yields them water, and in it hydrogen, they absorb also into their being a small amount of mineral substances derived from the soil, such as potash, soda, lime, etc. When plants are burnt, it is the giving back to the air of the carbon they derived from it, that causes the flame and smoke. The ash they leave is the mineral substance they derived from the ground. Part of the ash that we obtain on analysis from coal, is so derived, but the larger part of it is from foreign impurities, such as mud and sand, drifted into the marsh and mixed up with the peat. A coal would be considered quite pure, if its ash were only that which was derived from the plants that formed it.



Trees and vegetation in dying and rotting, yield up their carbon to the air, in the same way as by burning, so for ages the living forest has been above ground, its roots in the subsoil or under clay, and between the two, a mass of decaying vegetable mould. If it were not for this decay a large portion of the world would be buried under thousands of feet of dead trunks and vegetation, instead of which, despite the growth upon growth of generations of forest, we have but a few inches of black vegetable soil to represent them, the rest having all passed off into the elements of the air, and been again and again reabsorbed by subsequent generations. Such is the history of dry forests and it is obvious that from them alone, without the assistance of some other agency we could never have derived our thick coal beds. That agency was water, proofs of whose existence in connection with the coal-beds are very apparent in the sandstones, which show a net-work structure, as if they had been cracked all over and the cracks filled up with some harder substance, these are fossil mud-cracks, the same as we see in the bed of a pond that is drying up, tracks of worms are found, and in some coal fields foot-prints of saurians that crawled over the mud. Though the elements of vegetation pass off into the invisible air on dry land, if you submerge these trees and vegetation in water, they retain many of their elements, especially carbon, the tree only rots in part, becomes water-logged, and gradually sinks into the soft blackened substance of peat, and if afterward by sinking of the land, it is in this state covered deep with sediments, it is turned into coal. The conditions most favorable for coal formations, appear to be, a damp, moist, warm atmosphere, a rank vegetation, low-lying swampy land receiving sediment washed into it from higher land, gradually subsiding beneath the waters of a great lake or sea. The northern hemisphere contains the most coal, such as northern Europe, America, and China, the largest but least known fields are said to be in China.

Chemists tell us that vegetable matter buried in the earth, exposed to moisture and excluded from the air, decomposes slowly, evolving carbon dioxide, and parting with some of its original oxygen, in this way vegetation is gradually changed to "lignite," containing a greater proportion of hydrogen than wood,



continued decomposition aided by pressure and some heat changes lignite to bituminous coal by discharge of carburetted hydrogen, that is, the common gas we illuminate our streets with. The inflammable gases escaping from coal, causing such fearful accidents in mines, contain light carburetted hydrogen and olefiant gas. The disengagement of all these volatile gases by slowly applied heat, gradually transforms the bituminous coal into anthracite, and the next and last stage is graphite.

The extent to which coal has thus been changed by parting with its gas, is related to the amount of disturbance undergone by the strata enclosing it, the numerous cracks thus formed acting as escapes for the gas. The increased heat derived from the interior is also an important factor in the change. This, as we have shown, is well illustrated in the region about Crested Butte and Glenwood in Colorado, it is also forcibly exemplified in the coal fields of the eastern states. The coal strata west of the Alleghanies are horizontal, and the coal bituminous, but going south-east, the strata become disturbed, and the same seam progressively debituminized, in proportion to the greater folding of the rocks. At first the coal yields 50 per cent. hydrogen, oxygen, and volatiles, then 40 per cent. as the folds commence, till on entering the mountains, where the folding and faulting are at their maximum, these fall to 6 per cent. (anthracite).

The gradual change from wood to anthracite is shown in the following analyses from Huxley's physiography.

	Carbon.	Hydrogen.	Oxygen and Nitrogen.
Wood (oak) . . . .	48.94	5.94	45.12
Peat . . . . .	55.62	6.88	37.50
Lignite . . . . .	69.94	5.95	24.11
Bituminous coal (New- castle, England) . .	88.42	5.61	5.97
Steam coal (Wales). .	92.10	5.28	2.62
Anthracite . . . . .	94.05	3.38	2.57

#### NATURAL HISTORY OF COLORADO COAL BEDS.

The coal beds of the Laramie group in Colorado were formed at a time when the continent and these mountains (then only islands) were gradually rising from a protracted marine



condition that had more or less prevailed in previous periods, from the Silurian to the Upper Cretaceous. An interior arm of the sea, dividing the continent and extending from the Gulf of Mexico to Alaska, was being drained off by the elevation of the lands east and west of it, leaving as it retired a good many brackish lakes behind it, to be gradually rinsed out and become fresh as the elevation continued, by freshwater streams descending from the higher lands. Hence it is that we find brackish water-shells, such as oysters, in great abundance at Marshall and Newcastle, generally near the lowest coal seams and at the beginning of the group; but in the upper portions, such few shells as are found, are of fresh-water origin. Along the shores of these lakes and the borders of the retiring sea were peat-swamps fringed with luxuriant semi-tropical vegetation, and receiving sediments from material washed from the higher and rising land. This accumulation of sediment was accompanied by a slow subsidence of the marsh area, the amount of which may be measured roughly by the thickness of the beds represented in the coal group. Thus, on the foothills east of the range, it is rarely as much as 1,000 feet; but on the other side, in north-western Colorado, the subsidence must have been greater, as we have upwards of 3,000 feet of sandstones and shale in the Laramie group. Elevation of the granite mountain-region was apparently going on at the same time and with about equal steps with the subsidence, for we find the Laramie strata along the mountain border invariably tilted up at a greater or less angle. The gradual emergence of this part of the continent from the domain of the sea is beautifully shown in studying the strata a little below the coal.

We have below the coal the enormously thick shale-beds of the marine Fox-Hills and Colorado Cretaceous groups; the limestone of the Colorado group and the fineness of the shales show them to represent the bottom of a moderately deep sea; the shells prove their marine character. Towards the upper part the shales become sandier, implying shallower water; a great abundance of shells are found also, whose habitat is never in very deep water, but commonly near shore. Finally the sandy shales pass into thick, massive, yellow sandstone, in which we



find numerous casts of seaweeds which grow near shore. A few feet above this are the shells of oysters and of other shell-fish which frequent brackish water; and a few feet above them again traces of land vegetation, followed by a coal seam, generally a thin one, showing that land life, such as trees and vegetation, were not as yet abundant; but in a few feet more we have a heavy coal seam, with sandstone beds above it containing leaf fossils in abundance, and several other but usually smaller seams to the top of this series.

These coal-bearing beds of Colorado, which are the same in general characteristics all the state over, were called by Hayden the Laramie group, because of their prominence in the neighborhood of Fort Laramie in Wyoming, where extensive coal-fields, covering 30,000 square miles, have long been developed. They consist principally of sandstone and shales, with more or less coal seams at intervals, and, as we have said, are partly of brackish and partly of fresh water origin. The physical changes we have alluded to "affected," says Dr. Newberry, "the whole great interior basin of the continent, as we find the characters and relation of the Colorado, Fox-Hills and Laramie groups to be continuous along the flanks of the Rocky Mountains quite across the State of Colorado, and from northern Wyoming to southern Chihuahua in Old Mexico." And again, speaking of the coal-fields of western Colorado, he says: "This coal-field is but the eastern margin of a sheet of upper Cretaceous rocks, which reaches across the Rocky Mountains to the Wahsatch, everywhere carrying coal, but the influences which have given such varieties and excellence to the coals of western Colorado, viz., the eruption of igneous rocks, do not extend west, and Utah coals are soft, less varied and less pure."

The great coal fields of the Eastern states belong to a far earlier period of the earth's history than those of Colorado; they are for the most part in the Carboniferous, whilst those of Colorado are in the upper Cretaceous, periods separated from one another by millions of years and by thousands of feet of rocky strata. We have the representatives of the Pennsylvania Carboniferous in Colorado, but it lies at least 5,000 feet below



our coal-beds. The Carboniferous in Colorado is rarely productive of any coal; it consists principally of limestone, grits, sandstone and shales, yielding us, however, material of great value, for some of our most important silver mines, such as those of Aspen and Leadville, are located in this series. That it is related to that in Pennsylvania is evident from the fact that we find in the middle group of this series, among thick beds of shale and sandstone, a few of the same peculiar fossil trees that characterize the Carboniferous in the Eastern states and the world over, such as the remains of gigantic reeds ("*Calamites*") and of curious trees called "*Lepidodendra*"; also in a few cases we find beds of black carbonaceous shales, as if coal had tried to form, but failed from lack of material; and lastly, in a few localities, actual thin seams of good coal like that of the Eastern states—in only one or two districts, however, is it within minimum workable size—and is utilized only in places remote from our Cretaceous coal. Thus at Telluride, in the San Juan mountains, a seam of very good coal (three feet thick) is developed in small quantities, meeting with a ready local market at the high price of \$10 per ton.

This shows us that the Carboniferous is with us, but that the circumstances under which it was laid down in this region were different from those in the East and not favorable to coal-making; probably they were more marine than those in the Mississippi Valley, where such great and valuable coal deposits exist. The trees and vegetation of the Carboniferous were of a very different order from those of our Cretaceous, which latter are closely allied to those now living; this may have something to do with the different character of the coal in the two regions. There were the same swampy, "watery woodlands" and peat-beds in both cases, but in the Carboniferous there was not so much high land as in the Cretaceous. The low-lying islands and continents were covered with a dense, luxuriant vegetation in the Carboniferous, of a peculiar kind and all of a swampy character. Gigantic tree-ferns, equally gigantic reeds and club-mosses, and other forms unlike any now living, united with a peaty undergrowth to give us those coal-beds. In the case of our Cretaceous beds there was comparatively high land in the



neighborhood, clothed with both hard and soft-wood trees, very similar to those of the present day. These, with bordering peat-swamps, gave us our Colorado coal.

The coal of the Eastern States being of older age, has been covered with a greater thickness of sedimentary rocks, and for a far longer time than our newer beds, which fact, together with the heat engendered by depth, has concentrated their carbon, making them very compact and of a superior quality; but, to make up for this deficiency, our coals have often been subjected to greater heat, and to a certain amount of mechanical pressure by the greater elevation, disturbances and volcanic eruptions of our greater mountain system, which have brought about very nearly the same results in the character of the coal, especially in certain of our districts.

It is often difficult to persuade Eastern people, unacquainted with Colorado, that we have in this and adjoining States coal fields of greater area, with thicker seams, and often equally good coal, as in their time-honored Eastern localities. The statements that we have anthracite as good as that of Pennsylvania, bituminous coals in beds of great thickness, comparing favorably with theirs; coal again of such remarkable purity that it will yield coke as good as that of the far-famed Connellsville field; all these are looked upon as exaggerations. If these Western States had been discovered first, and had become as thickly populated as the Eastern States now are, it is a question whether Colorado, Wyoming and adjacent territories would not have been considered as the great coal area of the United States. We stand now about fifth in the rank of coal-producing States, but as to our undeveloped resources, we rank among the first.

When first examined by Hayden, many years ago, our coal-fields were unfortunately dubbed "The great lignitic formation of the West," merely from their geological position, seeming to agree with that formation which carries the inferior "lignite" of Europe, without any respect to the character of the coal contained in these beds. Thus, by persons outside of Colorado, our coal was supposed to be inferior "brown lignite," which is little better than peat. It is true that we have a class of coals, locally distributed along the plains, whose analysis, from the amount of fixed carbon



and water shown, brings them within the chemical definition of lignite; a lignite, however, of a very superior quality.

This character of coal is limited principally to one field, that of the Denver basin, forming but a small fraction of our coal area, while from Canon City south to Trinidad, the same coal-beds are no longer lignitic, their per cent. of fixed carbon, their firmness and other qualities raising them to the rank of bituminous or semi-bituminous coals of a high order, while again, the same formation over the range, all through the western and more mountainous portion of Colorado, yields coal which, beginning at bituminous, ascends in the scale through coking coal to genuine anthracite. Dr. Newberry, of Columbia College, who has had perhaps the largest experience of any man in the coal fields of both the Eastern and Western States, speaking of the coal-fields of northwestern Colorado, says: "They contain sometimes as many as eight to ten seams of coal, some of which occasionally reach a thickness of 20 feet or more."\* Often 40 to 50 feet of workable coal may be seen in the same section, and this of a quality which will compare with any known in the world. It should also be said that, owing to varied and peculiar conditions, the coal forms several varieties, each of which has its special uses in the economy of civilization. Here we find anthracite, as hard and bright as any of that mined in Eastern Pennsylvania—semi-bituminous coals similar in composition to those of Blossburg, Cresson and Frostburg, but more compact and pleasanter to work, transport and use—bituminous coals which yield a coke as good as that of Connellsville or Durham, and open-burning or furnace coals, similar in character to the famous Briar Hill coal of Ohio, and of equal value. Though so unlike in other respects, these coals have this in common, that they are of unusual purity, sometimes containing two per cent., and rarely more than five per cent., of ash, with little sulphur or phosphorus.

Some approximate estimates of the areas covered by the fields of this western portion of the continent will give a rough idea of the vastness of our coal resources. At least twenty thousand square miles of Colorado are underlaid by coal.

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\* One seam alone is 45 feet thick.



Texas has thirty thousand square miles, Dakota one hundred thousand square miles. New Mexico has at least six hundred thousand acres of coal, ranging from lignite to anthracite; Wyoming, twenty thousand square miles; Montana, twenty thousand square miles. Of Utah we have no estimate, but it is probably quite as great as any of the others.

It must not be supposed, however, that all of the coal in this vast area is available.

It is only within the last year or two that people, both in Colorado and in the East, have begun to recognize the magnitude and importance of our coal fields, a recognition arising partly from the opening of new railroad lines, increased population, and the influx of Eastern speculators. Where one or two companies formerly enjoyed the monopoly of nearly the whole coal trade and coal fields, on the strength of a few mines, there are now dozens of companies, whose mines are scattered over the whole area, and speculators are constantly on the lookout for coal lands, some in the proximity of already established railroad routes, others in tracts of country where they hope railroads may eventually come, while, in addition to these, there are hundreds of square miles of coal field that are not even taken up, still less developed, containing great bodies of coal outside of the probable future line of any railroad for a long time to come.

#### PROSPECTING FOR COAL.

Nearly all the coal that has been opened up in Colorado was first discovered by accident, by the digging of a well or a foundation, or by the outcrop of the coal itself, plainly seen along the banks of some stream; in fact, almost every stream that issues from the mountains will show more or less coal at a certain point along its banks. That point is not generally difficult to find, when the strata are well upturned and exposed to view. By starting from the granite and walking down stream across the upturned hogbacks, as shown in the sections accompanying this work, you will generally find next to the granite a series of red rocks (Jura Trias), followed by a prominent hogback of gray sandstone (Dakota group), then a valley or meadow of shales



(Fox-Hills group), and lastly an outcrop of white or rusty sandstones (Laramie group), among which last you will find the first coal seam.

You will recognize the Laramie sandstones by their containing a good deal of oxide of iron, and iron concretions, together with fossil mud-cracks, impressions of fossil leaves, and specks or thin seams of lignite, you will find the coal somewhere within a hundred feet among these sandstones. Its appearance on the surface will be little more than a dark brown stain, but followed down a few feet, it will gradually pass into solid coal.

Should the rocks in the vicinity be obscured by vegetation, soil, or surface drift, you will rarely find the coal formation less than a mile from the granite mountains, and often more than that, as a thickness of from five to ten thousand feet of upturned strata usually intervenes between it and the granite. If any of these strata are exposed, such as the Dakota hogback, you know that the coal lies still above it (geologically) by perhaps half a mile; if you find a limestone or shale with marine shells, you may be pretty sure you are in the Colorado or Fox-Hill group, and that the coal does not lie very far above it.

On the flatter prairies or table lands, it is to be remembered that though you may find indications of fossil-leaves, and even very thin seams of coal, you may be on the extreme upper portion of the coal formation, or even on the Tertiary series still above that, and that the main coal seams lie generally near the base of the Laramie group, probably one thousand feet below you. A good deal of profitless boring and shafting has been done on the plains owing to some well or other, as at Denver, striking some thin seam of coal, encouraging prospectors to go down in futile attempts to reach a larger and workable seam.

In the plateau region of southern Colorado, the coal is generally so clearly shown in almost every cañon, that prospecting is limited to a mere use of your eyes and to good judgment in the choice of a seam or of a suitable location. For the same reasons as just given, the Fox-Hill shales with their cap of massive "fucoidal" sandstone, like the "farewell rock" of English coal miners, should generally be considered as the limit downwards of the coal, and all prospecting should be done on strata lying above it.



If coal seams are lost by faults, the common rule "that the foot wall of the fault rises, and carries up the coal with it, while the hanging wall similarly falls," may be generally followed to advantage. In southwestern Colorado the prominent yellow "fucoidal" sandstone, capping the shales of that table land region, has been a useful guide to me in knowing where coal does, or does not exist.

If you are looking for coking coal or anthracite, seek those districts characterized by the greatest amount of overturning of the strata and outpouring of eruptive rocks, such as the region of the Elk mountains. On the prairie or flatter portions you will generally find the coal to be "lignite" or "bituminous" and neither coking nor anthracite, unless it be locally made so by the presence of eruptive rocks. After finding any coal its quality should be tested by analyses, especially as to its coking qualities, for costly works have been erected before now in Colorado in the neighborhood of coal mines with a view to producing coke, and the coal was found on trial not to make coke at all. In such cases a simple laboratory experiment, taking but a few minutes and costing a mere trifle, would have saved thousands of dollars.

#### LOCATING COAL MINES.

In locating a coal mine with a view to development, the first thing to be considered is its proximity to a railroad, for without a railroad a coal mine is helpless. Having found a series of coal seams of workable size, i. e., not less than four feet thick, the best seam should be selected, not for its width so much as for its freedom from partings of shale or "bone" and its physical or other properties as determined by analysis, for quality rather than quantity will generally command the market, particularly if the coal has to be shipped to distant parts in competition with others. A coal seam with many shale partings at different levels in the seam, should be avoided, as it is impossible to work the coal entirely free from them, and a great admixture of shale would give a high per cent of ash, which would reduce the value of the coal, especially for coking purposes. Again, if there are only one or two partings, much depends upon their position in the seam, if near the roof it may be left with perhaps a foot of coal



above it, to support the roof, and the remainder of the seam be developed; if the parting occurs about the middle of an average size seam it is inconvenient, as in trying to separate it from the coal, the lower portion of the seam must first be worked back, then the parting be carefully taken out by itself, and lastly the top portion worked. Partings will sometimes gradually fade out in portions of a mine, but at others they will continue with remarkable pertinacity for a great distance.

If a nearly horizontal seam is selected, such as those near Trinidad, it is desirable, if possible, to develop it at some point where its gentle dip of a few degrees will be toward the outlet and discharging point of the mine, so that the laden cars can be drawn out on a gentle incline by gravity alone, and the empty cars hauled in by mule power. If this cannot be attained, steam power and a revolving wire cable is necessary. The rocks around should be examined to see if there is any indication of faulting, or whether dykes of lava cut through the coal seam. Again, it is advisable, when possible, to open the seam on the face of a cliff or hillside at a convenient distance above the bottom of the valley or prairie to allow room for a dump, and also for the building of a raised tramway, running directly out of the mine to the tippie, from which the coal can be shot down into railway cars running beneath. Sometimes the opening has to be made at a considerable height up the hillside, then a double gravity tramway is necessary from the mine to the tippie.

In the Trinidad region most of the mines are developed up little ravines, which often combine many of these desirable conditions. A village grows up about a coal mine of importance, and this may be located on a flat in the valley. Proximity to water is an important point, as a great deal has to be used at the mine; and should a coking plant be erected near by, an immense amount of water has to be used, which at some points in Colorado is pumped up by steam from the main river.

The main entry, at least, should be wide, high and commodious, whether the mine is to be worked by the "Long-wall" or "Room and pillar" system. The tributary side-levels need not be so roomy; the slope of the side entries, when possible, should incline towards the main entry. If the dip of the strata



be greater than five or six degrees, the grade of the track may sometimes be lessened by running it diagonally across the dip instead of entirely with it.

It is not desirable as a rule to drive shafts or other workings much below the water level, as the mine would then be very wet, needing pumps, and be much more liable to fire-damp and other gases than higher up the hill, where such gases may have a natural outlet through the exposed edges of the strata.

In developing a large area, the workings should as much as possible be concentrated at one point and not scattered over the field, involving the expense of a different plant for every separate opening. If two or three openings are made at different points, they should be so located as to be connected with one another by tunnels or tramways tributary to one main discharging point.

Such are a few general suggestions, but much will depend on the character of the location and the judgement of the engineer in planning the development according to circumstances.

The demand for coal varies a good deal according to the season, being usually greater in Winter than Summer; it is common, therefore, to work a greater force in the Winter than the Summer, and in some years more than others. The rate of wages varies in different parts of the State, according to the ease or difficulties connected with the local development and other local circumstances. In nearly all the mines an industrious miner can, if he pleases, make better wages than at almost any other laboring work of a like nature.







## CHAPTER II.

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“Denver Basin” Coal Fields.







## Chapter II.

### THE "DENVER BASIN" COAL FIELDS.

By the Denver Basin we understand generally that area of country, with Denver as a center, lying between Boulder on the north and the Divide country around Sedalia and Palmer Lake on the south, and between the foothills of the range on the west, and an undetermined line some twenty or thirty miles on the plains beyond Denver to the east.

In this area are a number of coal mines tributary to Denver as a center. We shall give first the geological features of this area, and then describe in detail the different coal districts.

The geology of this basin has received a good deal of attention, first by the Hayden Geological Survey, and of late by Messrs, Eldridge and Cross of the present survey. The writer, also, has spent many years in this basin studying its geology.

The Hayden Survey sketched out in a masterly manner the leading geological features, which have been elaborated by the present survey. The latter has also discovered some important facts in the divisions of the strata which were not before recognized, such as the existence of two distinct groups or subdivisions of the Tertiary, called by them the Arapahoe and Denver Tertiary beds, which were formerly included in the Laramie Cretaceous and supposed to be merely upper portions of that period.

Portions of this area are occupied by the seemingly horizontal strata of the plains, and portions by the same strata upturned along the mountain border, in a series of ridges, commonly called "hog-backs." The uplift of the great range itself, consisting of rocks of a granitic type, is the primary cause of this movement among the strata.

Along the foothills, by reason of this upturning, we have an opportunity of seeing clearly the nature of the various strata that are buried from our sight beneath the plains, and can also find



the exact position among these strata of that particular set which contains the coal. An approximate idea can thus be obtained, by measuring the upturned strata, of the thickness overlying the coal, and at what depth it might be expected beneath the prairie.

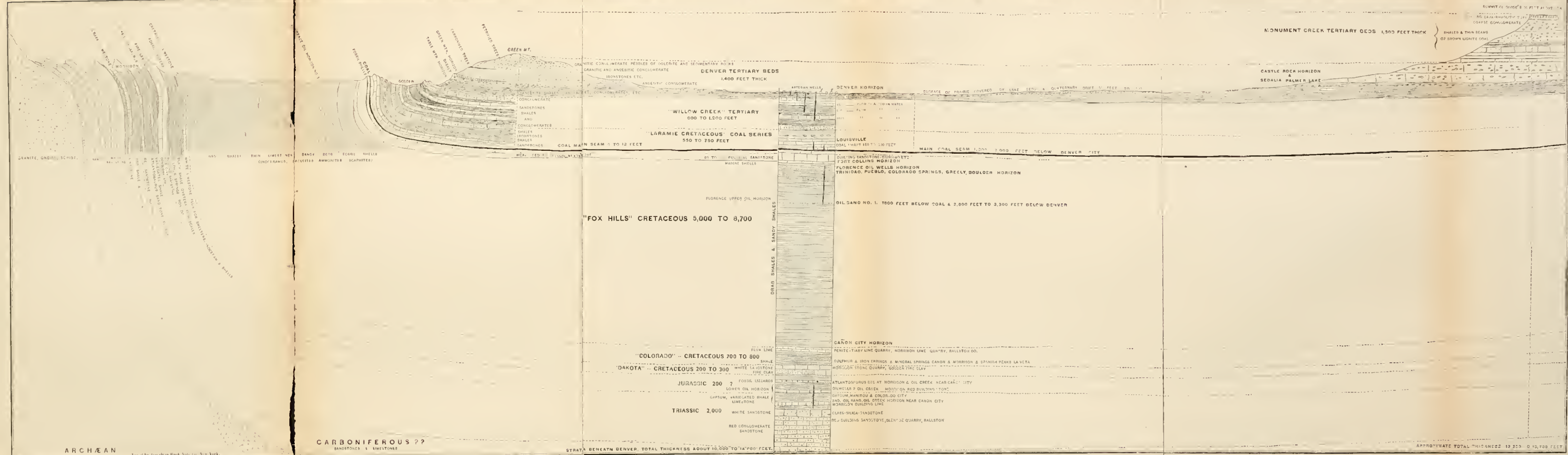
DESCRIPTION OF THE GENERALIZED SECTION.—(PLATE II.)

In the generalized section we have endeavored to show these points, and have also indicated the different geological horizons upon which some of our principal cities along the plains and foot-hills are located, both within and beyond the boundaries of the Denver Basin, also their position relative to coal. In some cases it will appear that, by great surface erosion, they are situated on strata that lie far below the coal horizon, so that if borings were made immediately below the streets of those cities, coal would never be encountered. In a few cases cities are actually located above or upon the coal-beds; sometimes they are so high above them that it would take, as in the case of Denver, a bore over 1,000 feet deep to reach them; in others, as at Louisville, the coal lies but a few hundred feet beneath the houses of the town. It must be observed here that we confine ourselves to the exact locations of the cities themselves, for in several cases, cities are located near coal-beds, as Trinidad for example (which is in the old bed of a river), below which there is no coal, while on the bluffs immediately above the city, and not two miles from it, is one of the finest coal-fields in Colorado. We have also taken the opportunity, in the same manner as with the coal, to show what other products of economic importance are to be found at certain horizons, such as the horizon of oil, of flux-limestone, of fire-clay and building-stone. By referring the horizontal line to the place where it upturns against the mountains, the relative position of any particular stratum can be clearly seen. Thus Cañon City is located on horizontal shales overlying the Cretaceous flux-limestones, which are upturned only a few hundred yards from the outskirts of the city, and are extensively quarried close to the penitentiary. From this diagram may be seen what would be found at certain available depths immediately below Denver, and what lies too deep for









GENERALIZED SECTION SHOWING STRUCTURE OF THE "DENVER BASIN" THE DEPTH & POSITION OF ECONOMIC PRODUCTS BELOW SURFACE, AND EXPOSED IN THE FOOT HILLS; GEOLOGICAL HORIZONS OF PRAIRIE & FOOT HILL CITIES & THEIR POSITION RELATIVE TO COAL, ETC.



our means of boring. From ignorance of such geological facts, borings for coal have often been made and money expended, where a knowledge of the strata would show that no coal could be found, either by the location of the bore (as for instance on the Divide) being too high above the coal to reach it, or as in the case of Pueblo, being below the coal, making the task hopeless.

The dotted lines in the upper part of the diagram show some of the strata that once existed over this area in great thickness and have been removed by erosion.

#### DESCRIPTION OF STRATA OF DENVER BASIN.

We will now describe the strata, beginning from the bottom. Were we in the field we could best do this at the outlet of one of our cañons, such as that of Bear creek, Clear creek, Ralston or Boulder, where streams have cut deep through the upturned strata of the hogbacks, and shown the character of each stratum or group of strata, as clearly as a row of books on a library shelf.

Beginning with the granitic mountains which belong to the Archæan age, as our starting point in the Denver Basin, the first set of strata we find leaning upon them are the Triassic red sandstones. (The Silurian and Carboniferous are not exposed in the Denver Basin, but are found further south at Manitou).

Next come the Jurassic variegated marls, clays and sandstones, followed by the Cretaceous, with its beds of sandstone, limestone, and enormous thickness of shale, and lastly the Tertiary, consisting of conglomerates, sandstones and shales; we may add yet another group, capping and often concealing all the others, viz., the Quaternary, consisting of cobble stones, pebbles, gravel and clays, strewn over the surface by glaciers, rivers and lakes.

It is to be observed that though we are treating of the Denver Basin, the same set of strata, and many of the same geological features, are repeated again and again in different parts of the State, as will be seen by comparing the various sections accompanying our reports on the different coal districts. The thicknesses may differ locally, but the leading characteristics of the rocks remain much the same throughout the State, so that a section once thoroughly mastered at one locality is a key to all the rest.



## ARCHÆAN AGE.

The rocks of this age constitute the great mass of the mountains proper, and consist mainly of gneisses, schists, and some massive granite. Of late attention has been drawn to our fine red and gray granite as a building stone. The rocks of this age also carry much of our precious minerals in fissure veins.

## THE TRIAS.

Resting on the Archæan with a easterly dip of from thirty to forty-five degrees, are a series of beds characterized by their red tint. Eldridge includes in the Trias all the red beds between the granite and the paler tinted, softer shales of the *Atlantosaurus* beds, which last alone he seems to consider as proven Jurassic. In the classification of the Hayden survey we used to call the massive beds Trias, and class the softer red beds with their included limestones and gypsum among the Jurassic. He divides the Trias into two groups, the lower consisting of about 1500 feet of massive red conglomerate, capped by a cream-colored massive quartzose sandstone, with gritty layers, and near the top small, ferruginous concretions, which, by weathering out, give a singular pitted appearance to the rock. The upper 600 feet consist of fine brick red sandstones and shales, with narrow intercalations of limestone near its base, also variegated clays, layers of gypsum and pinkish sandstone.

From the Trias fine red building sandstone is obtained at the Glencoe quarries on Ralston creek, and at Morrison on Bear creek, also white siliceous sandstone for glass manufacture. The limestone, also, is quarried and burnt along the foothills.

No fossils have been discovered in this series in the Denver basin, but the writer found some fossil leaves and insects near Fairplay, (South park), which by some geologists are attributed to the Trias and by others to the Permian.

## THE JURASSIC.

If we restrict the Jurassic to that series of beds in which the *Atlantosaurus* or great Dinosaur remains were discovered by the writer some years ago, then the series is not more than 200 feet



thick, and consists principally of marly clays and shales of a pale, ashen, greenish or maroon tint, overlaid by the brown "saurian sandstone." This sandstone, between ten and twenty feet thick, is characterized by little white spots and concretions of clay; it was in this that we first discovered the bones of the Dinosaurs, or great lizards, at Morrison, afterwards we found them continuing down into the clay. We found fragments of bone at the bottom of the "hogback" and traced them up to the sandstone ledge whence they had fallen. We dug out parts of several monsters, one of them was at least eighty feet long and stood twenty-five feet high, its thigh bone was between eight and nine feet long; these are the largest known land animals. The *Atlantosaurus* was a huge lizard, something like a gigantic alligator, with a long, thick neck and small head, a long, powerful tail, and a body of elephantine proportions, mounted on stout, strong legs. Its habits were herbivorous like the hippopotamus. Another smaller species was covered with coats of mail, armed with long spikes. The remains of turtles, crocodiles, fishes, and a few fresh-water shells were found with these bones; the remains are all in the Yale museum. The beds are of fresh-water origin and continue to the north into Wyoming and to the south to Canon City. In Wyoming, below the Dinosaur beds, we found marine Jurassic fossils, such as the skeletons of the *Ichthyosaurus*, (*Sauranodon*), or fish-lizard, also *Belemnites*, (the internal shells of cuttle fish), *Ammonites*, *Nautilus*, and other marine shells; in that region there appears to be a lower marine group in the Jurassic as well as an upper, fresh-water one.

The Jurassic is remarkable as the horizon in which petroleum was first found in Colorado, on Oil creek, ten miles north of Cañon City, many years ago; the horizon which at present yields so much oil at Florence is in the Fox-Hills' group in the Cretaceous.

#### THE CRETACEOUS.

This great series was divided by Hayden into six groups from peculiar characteristics in each group, which he named respectively the Dakota, Fort Benton, Niobrara, Fort Pierre, Fox-Hill, and Laramie, from localities where he happened to study them, or where they were typically shown; the present geological survey



makes only four divisions, the Dakota, Colorado, Fox-Hills and Laramie, the Fort Benton and Niobrara being included in the Colorado, and the Fox-Hills and Fort Pierre in the Fox-Hill group.

#### DAKOTA GROUP.

This is the basal member of the Cretaceous and consists of two hundred to three hundred feet of hard gray sandstone, underlaid by a conglomerate composed of fine pebbles of quartz, gray jasper and chert, firmly cemented together by a siliceous cement. Silurian fossil corals are sometimes found as pebbles in this conglomerate. Fossil net-veined leaves of the first Dicotyledonous trees known to have existed on this planet are found in the sandstones. The group is of fresh water origin. These sandstones being of superior hardness resist erosion and form prominent hogbacks among the foothills. A bed of dark blue-gray fireclay, five to ten feet thick, of excellent quality, lies in the middle of this group and is quarried near Golden for making firebricks which are exported all over the West for smelting furnaces and other purposes, and are but little inferior to the celebrated Welsh Dinas brick. The sandstones are quarried for building stone and also make good grindstones.

#### COLORADO GROUP.

The lower portion of this group consists of four hundred to five hundred feet of finely laminated black shales, with some thin beds of limestone; the upper portion, of a bed of limestone, forty feet thick, overlaid by shales of a pale yellow tint with some gypsum. The limestone of this group, being nearly pure carbonate of lime, is extensively quarried for "flux" for the smelters. Scales of fishes, oyster shells and shells of *Inocerami*, the latter not unlike large clam-shells, often as big as a saucer, are very characteristic. The entire group is about seven hundred feet thick; it is of marine origin, as shown by the fossils and by the presence of limestone.

#### FOX-HILLS GROUP.

This very thick group consists largely of shales, some sandstones and thin limestones. It varies in thickness, but, according



to Eldridge, maintains an average throughout the Denver Basin of eight thousand seven hundred feet, or one and a-half miles. At the top of the group the shales become sandier and pass gradually into a sandstone, sometimes quite massive, of a yellowish color composed of quartz and mica. This belt of sandstone is very persistent and usually lies at no great distance below the Laramie coal; generally it is full of many varieties of marine fossil-shells, such as *Cardium*, *Mactra*, *Tellina*, *Tancredia*, *Callista*, *Anchura*, *Nucula*, *Mytilus* and *Turritella*. Some of these shells resemble clams and cockles; others are spiral-shaped, like snails. A fine development of this sandstone may be seen at Fossil Creek, near Fort Collins, where innumerable shells are contained in cannon-ball concretions in the sandstone. It is the upper portion of this massive sandstone which we often mention in the course of this report as containing impressions of sea-weed. The scientific name of sea-weed is *Fucus*, and this variety is called *Halymenites*, hence Hayden and others speak of the sandstone sometimes as the *Fucoidal* and sometimes as the *Halymenites* sandstone. Its importance lies in its being the "bedrock" landmark of the coal, for the coal generally lies a few feet above this sandstone and is very rarely found below it. The entire group is of marine origin. Its economic value consists in its being the main oil-horizon of the State, as developed at Florence near Canon City. The wells there begin near the top of the group, a few feet below the "fucoidal" sandstone, and penetrate the shale for between fourteen hundred and two thousand feet, and then strike a porous, sandy layer, from which arise salt water, gas and oil together. As this Fox-Hills group is a very common formation in Colorado and covers large areas, it is probable that other oil fields, besides those of Florence, will be discovered in it in the future. The fucoidal sandstone at Oak Creek, Trinidad and other localities furnishes some of our best yellow building sandstone.

#### LARAMIE (COAL-BEARING GROUP).

This group occurs all over the Denver Basin. At the base of it is a series of heavy bedded sandstones, composed of clear, glassy quartz, one hundred to two hundred feet or more thick,



followed above by four hundred to five hundred feet of variegated clays and nodular ironstone concretions, containing plant remains. Along the foothills at Louisville, Marshall, Erie and Golden the coal-beds are associated with the lower basal sandstones, but at Scranton, twenty miles east of Denver, the coal is in the upper or shaly series.

## TERTIARY.

### ARAPAHOE GROUP.

For the recognition of these and the overlying Denver beds as a distinct formation from the Laramie Cretaceous, we are indebted to the researches of Messrs. Eldridge and Cross. They found that these beds lie unconformably on the Laramie, the materials of which they are composed, in the case of the Denver beds, differing remarkably from those composing the Cretaceous.

The Arapahoe beds are the lowest of three Tertiary groups; they were first called Willow creek from being shown very plainly on Willow creek, south of the Platte, the name being since changed to Arapahoe. At the base is either a thick conglomerate or a gritty sandstone, according to distance from the shore line of foothills; this is overlaid by gray shales with lenticular masses of hard quartzose sandstones and ironstone. The thickness of the group is from 600 to 1200 feet, the basal conglomerate is sometimes 200 and more feet thick, composed of pebbles derived from all the underlying formations even down to the Carboniferous, for pebbles with Carboniferous corals, (*Beaumontia*) are sometimes found in it. The pebbles have been silicified and are principally jaspers, agates, flints and petrified wood. The metamorphism of these is most observable near the old shore line. The bones of dinosaurs have been found in the conglomerate as well as in the Denver beds above them.

### DENVER BEDS.

This Tertiary formation lies in a basin hollowed out of the underlying Arapahoe group; it occupies a portion of the area about the city of Denver for 400 square miles.



The conglomerates and sandstones which form its beds are derived largely from fragments of andesitic lava, of whose out-pouring and subsequent destruction we have no other record; this peculiar composition mainly distinguishes it from underlying groups. The beds of fossil plants, so common in the Table mountains, belong to this formation, and a few vertebrate remains have been discovered; these are principally of turtles, crocodiles and dinosaurs. The tooth and scattered bones of a dinosaur were discovered by the writer and Mr. George Cannon in these beds at the base of Table mountain.

The lower portion of the Denver beds is best studied in the Table mountains, and the upper portion in Green mountain, near Golden. The total thickness is 1440 feet, of these, 525 feet forming the upper part of this mountain are a very coarse conglomerate of cobble-stones derived from all the formations. The lower part is of fine sandstone, conglomerates and clays, composed solely of andesitic material. Half way up Green mountain, on the west side, a small coal seam occurs, composed of carbonized stumps of trees, which still retain their original form and texture.

As the top of Table mountain corresponds to the base of Green mountain, if we add the two mountains together we obtain a complete section of the entire Denver group. That the group entered into the general fold of the mountains is shown by the fact that its lower members are lifted up to verticality near the base of Green mountain.

As to the age of this group. The Monument creek beds on the Divide, considered by Hayden as Tertiary, lie above these Denver beds and hence must be of more recent date, as further shown by the fact that they do not enter into the general fold as the latter do. The two groups are separable by the different constituents of their rocks, the Monument being mainly of material derived from the granite, the Denver beds from Andesite. Two-thirds of the Denver beds were removed by erosion before the deposition of the Monument group. From the absence of all granitic elements in the lower portion of the beds, Mr. Cross concludes that at that time, the mountains and foothills must have been overwhelmed and covered up by a deluge of andesitic



lava, so that the waters of the Denver lake could not reach the granite, but drew all the material of the lake beds from the lava, which must have been of great thickness, as the present thickness of the beds derived from its detritus shows. Of this lava eruption we have no other trace, for not an andesitic dyke even is to be found for a hundred miles at least from this area.

It was not until the waters of the lake had cut through this lava cap that they could get at the granite, and hence it is only in the upper portion of these beds that we find on Green mountain granitic boulders and pebbles of other rocks, mingled with those of the lava. This eruption of Andesite must have occurred in the interval between the deposition of the Arapahoe and Denver beds. The Basaltic lava, which at present caps the Denver beds on the Table mountains at Golden, is of later origin; its source is easily found in a large dyke north of the Table mountains near Ralston creek.

We gather from these facts that, after the Arapahoe beds were deposited in a fresh-water lake, a great deluge of lava issued from some unknown volcanic crack or vent, covering over, not merely the lake, but also the foothills and even the granite nucleus; that this lava-deluged country was again covered by a lake of fresh-water, deriving its sands probably through the medium of rivers pouring into it from the lava cap until that was consumed, and the granite and buried foothills were again exposed. During the existence of these lakes a tropical vegetation grew along the shores and in the marshes, crocodiles and turtles frequented the swamps, while dinosaurs and great mammals strode along on the dry land. Again, long after these events, a second outpouring of lava of a different variety issued from a fissure in the ground near the region of Ralston Creek, and the basalt from this poured into the, perhaps, still existing waters of the Denver lake, or at least over the beds once accumulated in its basin. Subsequent erosion has removed much also of that lava cap, exposing its source in the Ralston dyke, but sparing a portion of the cap, which now covers the two Table mountains at Golden, to tell the history of those ancient contests for supremacy between fire and water.



## STRUCTURAL PECULIARITIES OF THE DENVER BASIN.

The range has, according to Eldridge, a structure "en echelon," resulting from folding on an axis, which extends diagonally across the general trend of the mountains in a direction ten to twenty degrees nearer north-west than that of the range itself. By this an anticlinal arch is formed, the northern end of which disappears in the range, while the southern extends out into the prairie, and owing to its south-eastern dip, gradually disappears beneath its surface. Between the diverging southern end of this fold and the range proper is an accompanying synclinal trough, whose axis rises to the north-west. This structure produces a series of offsets from east to west in passing along the foothills in a southerly direction. On Big and Little Thompson, at Ralston and South Boulder, this structure is well shown.

## FAULTS.

The important faults in this area are due to the forces which uplifted the Colorado range, and are caused by lateral pressure at right angles to its axis, the greater folds breaking in faults parallel to their axes. At South Boulder a double peak has thus been formed, and north of Deer Creek the Triassic strata are twice repeated and a strip of granite is exposed at the fault line. Another set of faults are due to forces independent of the last, and are exemplified in the neighborhood of Coal creek and South Boulder creek. These will be described later. A third and local kind result from the extrusion of molten matter, as may be seen in the neighborhood of the Ralston dyke. The faults in the Golden field are the natural result of the extreme compression and parallel folding to which that area was once subjected. Some local nonconformities also occur there, which we will describe hereafter.

## COAL OF THE DENVER BASIN, BY GEO. ELDRIDGE.

The workable coal of the Denver field is confined to the Laramie group, and occurs at two widely separated horizons, one high up in the shales, where it is developed only in the eastern



part of the field, the other in the sandy series at the base of the formation, probably extending throughout the entire region.

The former field is of comparatively small extent. The presence of its coal has been proved northward as far as Scranton and southward to Coal creek (Upper Sand creek), its eastern limits still remaining undetermined. In both the localities mentioned it is within a short distance, overlaid by the Monument creek beds, though from portions of the intermediate area this group has been eroded, leaving the Laramie clays as the surface beds. Like all other coals of the Laramie, the material out of which it has been composed was laid down in a shallow local basin, and in its thickness varied greatly from place to place.

The lower horizon is the important one of the field, furnishing, as it does, nearly the entire amount of coal mined in the vicinity of Denver. The distinguishing features of this horizon are: First, the massive sandstones at its base, lying immediately upon the Fox-Hills, and characterized by a narrow median band of vegetable remains, sometimes altered to coal, the whole attaining a nearly uniform thickness of from 120 to 150 feet; second, an overlying zone of sandstones and shales in interchangeable proportions, in all, between fifty and seventy-five feet thick, through which occur the coal beds, and near the base of which is found, at certain localities, a calcareous sandstone, from one to four feet thick, in which are imbedded great quantities of fossil oysters, (*Ostrea glabra*), together with a few other characteristic Laramie forms; third, the immediate succession above of the great mass of Laramie clays and ironstones we have already referred to.

The strata of the lower coal horizon are exposed in a highly inclined position along the foothills as far north as Marshall, when, through the combined action of upheaval and erosion, they are suddenly brought into a horizontal position, or one in which they have a slight general dip to the southeast, and the trend of their outcrop becomes diverted in such a manner as to carry them well out on the prairie towards Erie, several miles to the northeast. In this part of the field, by reason of the faults, these beds have often suffered sufficient elevation to bring their coals either within easy reach of the surface; or to have caused them, under the influence of erosion, to be entirely removed from certain areas.



The coal of this horizon occurs in several seams, usually four to five, any one of which may develop to a workable size or diminish to the thinnest stratum of brown carbonized leaves or stems. The workable portions assume the shape of shallow lenticular bodies, from three to ten feet thick, and from a quarter to several miles in area; and since their presence or absence in a certain locality depends entirely upon the ancient conditions of deposition, the greatest uncertainty prevails not only as to their occurrence, but also as to their maintenance of even a workable width. To this cause is due the fact that the valuable beds along the foothills are so often interrupted, and that in the prairie regions the horizon, though it may be within a short distance of the surface, is completely barren. For the same reason, also, it may not be the same seam that occurs in workable size at the several mines along the foothills, and from their irregularity of occurrence and perhaps entire absence, no data exist for determining the individual seam opened at the various points. This point especially should be borne in mind in all observations upon the coal, the results of which cannot but be general for the horizon, instead of characteristic of any single bed in it.

Regarding the presence of bodies of workable coal in parts of the field other than those which have already been proven, it is very probable, from the above conditions of deposition and the frequency of occurrence of the known bodies along the present outcrop of the horizon, that other deposits of equal extent and quality exist beneath the great series of Tertiary and upper Laramie beds underlying the plains. Their great depth, however, which cannot be less than between 800 and 1,000 feet, even from the very point where they bend up sharply to a vertical position, taken in connection with the uncertainty of their existence under any definite tract of land, should, in view of the quality of the coal and of the capability of the mines already opened, not only in this field but also in other parts of Colorado, prevent any deep prospecting for coal alone for years to come.

#### CLASSIFICATION.

The coals of the Denver Basin are discovered, upon chemical analysis, to be divisible into three distinct classes, each of which



is confined to a certain portion of the field as at present developed, and, moreover, has for that portion a remarkable uniformity of chemical composition.

Of the divisions of the field thus referred to, one embraces the several areas under which the beds of the lower horizon have an approximately horizontal position, and includes the mines of Marshall, Louisville, Davidson, Canfield, Erie and Coal creek; a second is confined to the vertical beds of the same horizon, along the foothills, and extends from beyond the southern border of the area northward to Marshall; while the third conforms with the area of the upper coal horizon, in the vicinity of Scranton, on the Eastern border.

Class I. resembles in its physical appearance many bituminous coals of the East, and in its fuel ratio or the relation of its volatile matter to the fixed carbon, might be compared with certain coals of the lower portion of the Pennsylvania bituminous series, were it not for the proportionately great amount of water it contains and the fact that the total percentage of its fuel constituents is much less than that universally present in the Eastern coal. Regarding the water, moreover, it should be added that it cannot be considered accidental, but must be looked upon as a permanent characteristic of the coals of this class throughout the Denver field. This coal withstands weathering well, and is the highest in economic value of the coals about Denver.

Class II. has, on account of its average composition, as sampled at the present depth of the mines, been given a separate division in the scale, but there is reason to believe that its coals are but an altered condition of those belonging to Class I., and that, were it possible to trace the horizon in depth, the vertical beds into the horizontal, there would be found a gradual passage in their chemical composition of the one into the other, Class I., of course, having the representative composition of a bed in its original undisturbed position. In accordance with the very probable causes of this alteration, the change in composition would take place in the vicinity of the sharp folds at which the beds assume their different positions. The views just expressed arise from the facts that the horizontal beds have been least subjected to physical changes since their formation, that they and



the vertical beds are of the same horizon, and that in the deepest mine of the latter class (by some 300 to 400 feet) the samples from its lower levels are found to approach, in a very marked degree, the composition of the horizontal beds, the average of several analyses giving:

Fixed carbon . . . . .	42.93
Volatile matter . . . . .	34.19
Water . . . . .	18.85
Ash . . . . .	3.58
Sulphur . . . . .	.45
	<hr/>
	100.00
Specific gravity . . . . .	1.356
Fuel ratio . . . . .	1.25

Regarding, therefore, these two classes as originally one, a most peculiar anomaly occurs in the character of the alteration which the coal of the vertical beds has undergone; for, contrary to the evidence of other fields in like circumstances, it is found that there has been an actual diminution in the per cent. of fixed carbon, with the maintenance of the normal amount of volatile matter, an alteration the exact reverse of that which usually takes place. In explanation of this peculiarity, it has been suggested by Mr. Eakins that, after the lighter hydro-carbons of the normal coal had been driven off by the increased pressure, heat and crushing of the beds accompanying the folding of the Colorado range, their place was supplied by the partial breaking up of the heavier hydro-carbons remaining behind, and that thus the amount of carbon became diminished while the volatile matter remained the same.

Class III. is characterized by the excess of volatile matter over the fixed carbon, by the extremely large proportion of water contained, and by its high per cent. of ash. It weathers most easily upon exposure to the atmosphere, its color becoming a brownish black, and there develops, sooner or later, throughout the more exposed portions of the mass a decidedly earthy appearance in its character. It is, in fact, a lignite, if we regard this term as signifying merely a position in the scale of coals



above peat, and below the varieties of coal coming near the base of the recognized bituminous series. It is a class in which the fuel ratio more often falls below than exceeds unity, at least in America, and it contains those coals which are lowest in economic value in the Denver field.



### CHAPTER III.

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## The Golden Coal Beds.







## Chapter III.

### THE GOLDEN COAL BEDS.

We will commence with this field as best illustrating the geology of the Denver Basin.

The principal surface features are, the granitic Colorado range to the west, cloven by the canon of Clear creek, and to the east, the Table mountains, divided by the waters of the same stream. The latter belong to the lower portion of the Denver Tertiary beds. The intervening valley between the Table mountains and the range, 6,000 feet wide, is made up partly of horizontal, partly of steeply dipping sedimentary beds. The upturned beds lie nearest the range and are 3,000 feet in thickness, consisting of members of the Triassic and Cretaceous periods. The remaining space is occupied mainly by the Arapahoe Tertiary, overlaid by horizontal Quaternary lake beds and drift.

The upturned strata near the flanks of the mountains, owing to varying opposite dips, open up like a fan, as shown in plate III. If we consider these upturned beds as portions left by erosion of a series of once parallel folds, shaped like an S, leaning towards the range, we shall see that their apparently opposite dips are the result of unequal erosion; thus if the erosion spared the top part of the S that portion of the fold would be found leaning at a gentle angle upon the granite and dipping east; if by greater erosion due to softer rock this top were removed, and part of the upper portion left, the strata would appear to incline with a steep overturned dip to the west; greater erosion still would cause lower portions of the fold to be cut in the vertical portion, and finally the flat or lowest horizontal section of the fold would be exposed dipping gently east under the prairie. Thus we find a part of the Trias of hard massive conglomerate, resting at an angle of twenty to thirty degrees upon the old granite shore-line, dipping east and representing the top of the fold; the Fox-Hill shales and Laramie sandstones have suffered more from erosion



and dip seventy-five degrees to the west, as if overturned, representing the middle of the fold, but at 700 feet below the surface in the coal mine the strata become vertical and begin to turn gradually to the east; doubtless at a little greater depth they will be found practically horizontal, passing down beneath the prairie. The upturned Arapahoe Tertiary beds above the coal have had the fold almost entirely removed, so that in a short distance they show only their horizontal portions. These severe foldings and overturnings have been accompanied by faults, which are met with occasionally in the coal mine, generally nearer the outcrop than at great depths.

#### UNCONFORMITY OF STRATA.

It will be observed that, among the series of upturned strata, two or more important groups are missing about the middle, viz., the Jurassic and Dakota-Cretaceous, locally for a space of two or three miles, for north and south of that interval we find them in their average thickness, but gradually getting thinner and thinner as we approach Clear Creek till we lose sight of them altogether. This may arise partly from the extreme compression to which the beds have been locally subjected in endeavoring to accommodate themselves to the sharp curve in the outline of the granite shore line, through the center of which Clear creek issues from its canon. Beds may have been also faulted down between other strata, overlapped and lost to sight; or, again, we may suppose that the nature of the original shore line was at the time unfavorable to the deposition of thick sediments at this point, as in coast lines of the present day we find beaches deposited in bays, generally, where the shore line is low; if, on the other hand, the cliffs go abruptly down into deep water, but little sediment accumulates; or, it may be again, as Mr. Eldridge explains in an elaborate manner, that actual unconformity exists owing to the presence of a steep fold or arch at the close of the Trias, whose axis would about correspond to the line of the present Clear creek, and that this Triassic hill was inaccessible to the waters of the succeeding periods of the Jurassic and Dakota-Cretaceous.



## STRATIFICATION.

The first set of strata lying on the granite at an angle of thirty degrees is a red Triassic conglomerate, the pebbles composing which are derived from the adjacent granite, and are large, as might be expected from their close proximity to the old shore line, where the waves dashed against the rocks; the thickness of this group is about 500 feet. This is followed above by a bed of limestone belonging to the Niobrara group of the Colorado-Cretaceous, containing fossil oyster shells. It appears, then, that the whole of the Jurassic and Dakota, together with part of the Colorado, are missing at this point; a V-shaped, grassed-over interval, eighty feet wide, lies between the Trias and the Cretaceous, the Cretaceous dipping steeply west, the Trias east, hence at a point a short distance below the surface the two formations must come together in close conjunction. It is in this eighty feet gap that the problem of unconformity lies. We think it probable that a fault occurs at the same point between the opposing strata. Above the limestone are about 1,000 feet of Fox-Hills Cretaceous shales, with a few seams of clay ironstones at intervals. Towards the upper portion these shales become sandier, and we find numerous fossil marine-shells, among which little bivalve *Mastras* and sections of *Baculites* are very common. This belt of shales dipping steeply to the west is succeeded by the thick beds of sandstones and fire clay of the lower portion of the Laramie coal group for 400 feet; in these we find the first indications of coal in some half-dozen little seams, and towards the upper part of the sandstones the White-Ash seam occurs, six to eight feet thick, with an accompanying smaller seam a few feet below it.

Above the coal are three hundred feet of variegated clays and some ironstones. All the strata from the base of the coal to the top of Table mountain show remains of fossil vegetation and occasional thin seams of lignite.

These Laramie beds are succeeded in turn by the basal conglomerate of the Arapahoe Tertiary composed of small chalcudonic and granitic pebbles cemented by iron oxide. This is the last exposure for nearly 3,000 feet till we reach the Denver beds



at the base of Table mountain, the interval being covered by stiff clays, loose sands and boulders of a lacustrine origin, belonging to the Quaternary age. Among the latter on the north side of the creek, resting horizontally on the upturned beds of the coal, is a bed of "infusorial" earth of a white color and light weight, about six feet thick, whose area is undetermined. Under the microscope the characteristic forms of infusorial shells are distinctly seen; the deposit is of nearly pure silica. The lake-bed clays make good red brick and pressed brick. The Fox-Hill shales supply plastic clay for the pottery works, while the Dakota fireclay makes the celebrated Golden fire-brick, the best in America.

The Denver beds, which constitute the bulk of the horizontal strata of the Table Mountains for 600 feet, consist of conglomerates, sandstones, shales and clays, alternating with one another, and frequently passing into one another, composed of andesitic lava; the color of the strata is buff or ashen gray. The base of the formation and its exact relation to the Arapahoe series below it is obscured by lake-beds. Beds of fossil leaves are very abundant in these mountains, especially in a zone about half way up their slope; thin seams of lignite coal also occur, and much fossil wood, especially fragments or stumps of palm trees. These beds are capped by a thickness of 100 to 250 feet of columnar dolerite lava, which occurs in two or three surface flows, each flow being marked by a belt of spongy scoria, which once floated on the top of it. The solid portions show a rude columnar structure, cavities occur in the scoriaceous lava, formed by escaping steam; these are lined with exquisite crystals of zeolites such as Thomsonite, Chabazite, Natrolite, Apophyllite, Analcite, Mesolite, Scolecite, Laumontite and Stilbite, compounds of soda, lime and alumina in different proportions derived from elements of the lava, deposited by moisture infiltrating through it into the cavities left by the escaping steam. These crystals are either snow white, pinkish or transparent, and occur in various forms, some in needles and pyramids, others in long bunches of silken hairs like spun-glass, others in tufts like swansdown, others again in cubes, or like stars. Nothing can exceed the beauty of these tiny crystal-lined cavities, which sometimes contain in their center a large crystal of Iceland spar, resting on a setting of the other gems.



The source of this lava was from a fissure filled by a large dyke a little north of the Table mountains, crossing Ralston creek. The lava from this flowed over the level plain in a southeasterly direction, covering the Denver Basin between Ralston and Bear creek, and in the direction of Denver.

All these sedimentary beds were formed by water of some kind, the red Triassic conglomerates probably by the waves of a saline lake or sea, the lower Cretaceous by a shallow sea dividing the American continent in two, from north to south. During all these periods the continent was but little above the waves, and the present Rocky Mountains were but granite islands or reefs, till the close of the Fox-Hills and the beginning of the Laramie, when a general uplift took place, which was continued through part of the Tertiary and gave rise to a land and fresh water condition, in which we find, as in the coal-beds, great numbers of the leaves of trees and land plants, all of which are of a semi-tropical nature, as the presence of palmetto leaves, for example, clearly shows. That the beds of Table mountain were laid down through the medium of rivers and lakes of fresh water, is shown by the presence of fossil aquatic plants, such as the water-lily (*nelumbium*), reeds and sedges. Numerous ferns (*Woodwardia* and *Sphenopteris*) suggest a marshy undergrowth, among which, doubtless, the dinosaur, whose remains we found at the base of South Table mountain, made his home. Higher and drier land, however, must have existed, as we find the leaves of the oak, maple, poplar, beech, elm, plane-tree, sweet gum and magnolia. Fresh-water shells and bones of mammals are scarce. The coal was derived from the foliage of these trees mixed with that of the undergrowth, as in peat swamps of the present day.

The fiery origin of the andesitic material, out of which the waters formed the beds of Table mountain, has already been alluded to; and the second and later outburst of lava that now seals up those beds under 100 feet of molten rock, has likewise been traced to the dyke at Ralston. It is probable that cones and craters, like those of Vesuvius, may have existed on top of that fissure, all traces of those loose masses of scoria and lava having long since been removed by the denuding agencies which have left such striking evidences of their former power and



presence in the canon of Clear creek and in that which divides the Table mountains in twain. The horizontal Quaternary lake-beds also show the presence of wide lakes and bodies of water in their clays, of tumultuous floods in their pebbles and boulders, and of floating ice broken from the ends of glaciers higher up in the mountains, which carried out large boulders and masses of granite on to the waters of those lakes, and melting, strewed them over the bottom, now the grassy prairie. The courses of once broad rivers are shown by the wide and ample channels of the present diminished streams. The position of a very still lake is proved by the infusorial deposits, which are formed of the siliceous coats of microscopic organisms found in ponds in the present day.

The whole geological series shows a predominance of water in its construction, both marine, fresh and glacial, interrupted at intervals by outbursts of lava, caused doubtless by the continued upward rise of the great mountain mass which forced the weaker strata along its flanks to crack, and the molten fluid to pour forth. It is observable that nearly all mountain chains of the world are similarly flanked by a series of volcanic outbursts, and that in Colorado, on the flanks of each separate chain or range, we find such phenomena.

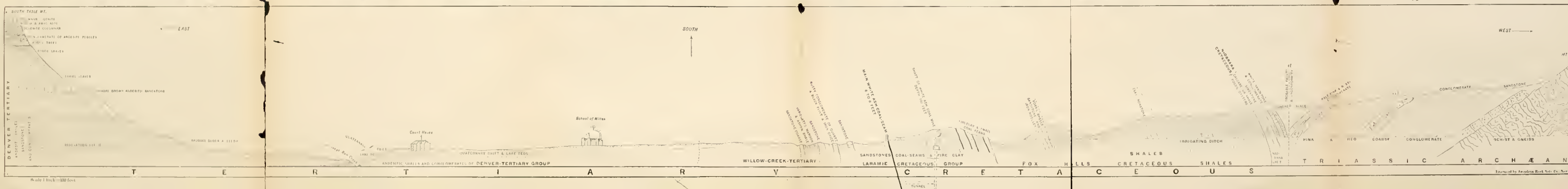
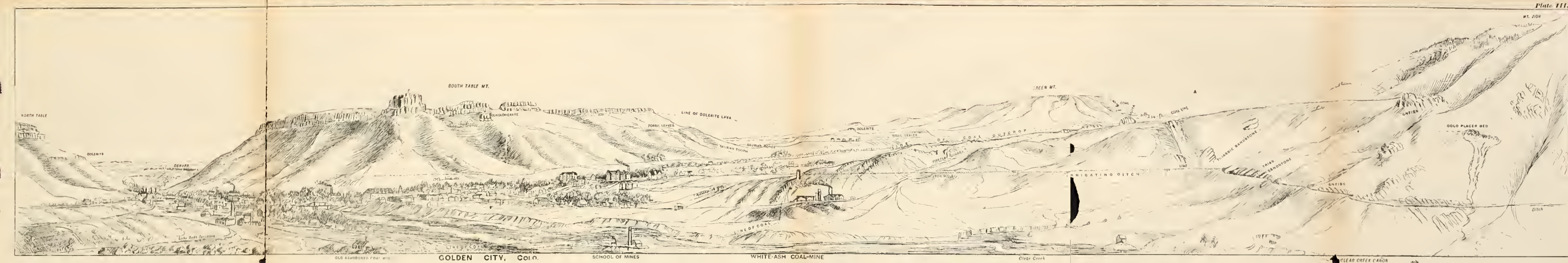
#### DEVELOPMENT OF THE COAL

The coal seam is developed on both sides of the river. The White Ash mine is on the south side and finds the main seam from seven to eight feet thick, dipping for the first few hundred feet between seventy-five and eighty degrees to the west. At between 600 and 700 feet it becomes vertical, and in the last few feet of the 730 feet deep shaft, shows an inclination to turn gradually to the east, doubtless at a little greater depth it will be found horizontal. The mine, despite the steep dip of the seam, has been developed by a vertical shaft which started in 137 feet west of the outcrop, and at the present depth of 730 feet is still forty-eight feet distant from the seam. In the first opening of the mine trouble was encountered by not meeting the seam where it was expected; the reason of this was, that the coal had been faulted or thrown back











from east to west, continuing down however, and cross-cuts from the shaft to the eastward again found the seam, which has continued to the present depth without interruption. From the shaft short cross-cuts are run to the seam, and then levels along the strike of the seam, north and south, at a vertical distance from one another of eighty feet. The south entry is 800 feet the north 900 feet long, the greatest length worked out of the north entries being 1,400 feet; of the south 800 feet; eight levels have been worked out. Below, that is, west of the main seam, at a distance of ten to twenty feet, is an accompanying smaller seam, three feet thick: the same little seam is found across the creek on the north, four feet thick, and at Ralston (six miles north) it is eight feet thick. Throughout this part of Colorado, the main seam is generally accompanied by a smaller seam.

#### CHARACTER OF THE COAL.

For about 200 feet from the surface the coal is soft, poor and slacks readily; from that point downward it increases in compactness and quality, till at the present depth of 730 feet in the White Ash mine it is of an almost flinty hardness, due to compression, partial metamorphism, and absence of surface influence. During the early stages of the mine they were obliged to mix superior coals from Cañon and Rock Springs with the White Ash coal, to supply the heat necessary for the kilns of the pottery works; in its present condition the coal supplies all the heat required. It burns comparatively slowly, and will keep in a fire well over night, throws out considerable heat, and slacks but little in the coal bins. There is very little shale mixed with the coal. It's superiority over the majority of coals of northern Colorado is shown by the accompanying analyses, and by the practical tests we have mentioned. It is unquestionably the best coal in this part of the State, and would command a better market if it were only developed on a larger scale, the output at present being but fifty tons daily, or 15,000 per annum. At present the market is confined to the local trade of Golden, and the mountain towns along the line of Clear creek.



Analyses of coal from the lowest level of the White Ash mine, by Professor George C. Tilden.

#### FIRST ANALYSIS.

Water . . . . .	13.89	per cent.
Volatile matter . . . . .	43.51	"
Fixed Carbon . . . . .	37.35	"
Ash (light yellow) . . . . .	5.25	"
	<hr/>	
	100.00	"
Sulphur . . . . .	0.59	"

#### SECOND ANALYSIS.

From samples taken 500 feet from the last.

Water . . . . .	12.82	per cent.
Volatile matter . . . . .	38.18	"
Fixed Carbon . . . . .	43.50	"
Ash (light yellow) . . . . .	5.50	"
	<hr/>	
	100.00	"
Sulphur . . . . .	0.595	"

NOTE — Recently a fatal accident occurred causing the death of ten men who were working at the end of the lowest level of the White Ash mine in the direction of the Loveland mine. The latter mine has for years been full of water. One of the upper levels of the White Ash, which if protracted would have made connection with the lowest level of the Loveland, has for a long time been on fire, and it is supposed that this at last burnt through into the Loveland, letting in the water which ran down the White Ash shaft and drowned the men working in the level below. The bodies of the men have not been recovered and the mine has been closed since the accident.

#### THE LOVELAND MINE.

This mine is on the north bank of Clear creek, on the same seam as the White Ash. It is, however, thicker here, averaging nine to ten feet, and the accompanying seam four feet. The shaft is 263 feet deep, the north entry 2,000 feet long, the south 1,300. About 30,000 tons have been taken from this mine since it was opened. It has been idle for some years owing to lack of operating capital. There are no faults or other obstructions in working this mine, and it offers the best facilities for opening up the Golden coal seam, owing to its close proximity to the railroad running up Clear creek canon from Denver to the mountain towns.



The same coal seams are traceable by outcrops and developments for many miles north and south of Clear creek. To the south, for a distance of some twenty miles towards the Platte river, the main seam appears of smaller dimensions, but beyond that, at the Cannon mine, west of Sedalia, the seam is again eight feet thick, stands vertical, and is said to be of good quality. To the north of Clear creek, for about six miles, the openings show the seam to be compressed and faulted by extreme folding and overturning, but on Ralston creek about eight miles north, where the folding is less and there is a more expansive development of the strata, the main seam is sixteen feet thick, and its attendant seam eight feet, making twenty-four feet of workable coal. Formerly these mines were extensively worked, but have been idle for some years; they offer great facilities for future development. Beyond Ralston the coal is easily traceable by its vertical hogbacks or outcrops, in a sinuous outline, till we reach Marshall, six miles from Boulder, where by reason of erosion combined with faulting, the coal seams lie at a gentle angle, dipping to the southeast. There is some prejudice about working these vertical seams on the ground of expense. The difference in favor of the horizontal seams, however, is not so great as supposed, and when depth is attained, it is compensated by the superiority of the coal. This brings us near to the northern limit of the Denver basin, and we pass by way of Erie to Louisville and examine together the Louisville and Marshall coal mines.







## CHAPTER IV.

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### The Louisville Coal Basin.







## Chapter IV.

### THE LOUISVILLE COAL BASIN.

This coal area is about twenty miles from Denver, on the east side of the railroad between Denver and Boulder. It lies in a natural basin in the prairie, sloping to the eastward. The average dip of the surface of the basin is to the south-east, at the rate of about one foot in one hundred feet, so that at the extreme limit of the basin, in a distance of between three and four miles there is a fall of 158 feet. The mines near that limit have to penetrate to a greater depth to reach the coal than they have to the westward, in the neighborhood of the town of Louisville. The dip of the underlying strata appears to be greater than the dip of the surface.

#### TOPOGRAPHY OF THE BASIN.

About ten miles from the town of Louisville, to the west, is the Colorado Front range, cloven by the cañons of Coal and Boulder creeks. These streams, issuing from the granite mountains, cut through a great thickness of sedimentary strata, uplifted almost to verticality along the flanks of the range. (See illustration of Marshall coal-fields, Plate IV.)

The strata, for some distance out from the mountain border, appear to have felt the influence of this uplift, for, for some ten miles down the course of Coal Creek we find evidence of faulting, and the coal over that distance is so broken up that it is not convenient for working. A portion of this disturbed district, as an elevated rolling prairie, forms the western boundary of the Louisville coal depression. A gentle rise to the north-west also forms the rim of the basin in that direction. The southern and eastern boundaries are defined by the bluffs forming the banks of Coal Creek. The stream curving around toward the east and north, partially encircles the lower portion of the basin. These bluffs rise between 100 and 200 feet above the depressed flat of the



Louisville basin. The coal basin is thus defined by natural boundaries. On two sides it is further limited by a fault.

The basin is a long, oval, nearly flat meadow, from three to four miles in length, by about one to one and a-half in breadth. There is reason to believe that this entire area is underlaid by a bed of coal of more or less workable thickness. The coal outcrops on the bluffs at several points around the edges of the basin. The thickest and most available portion of the coal-bed underlies the flat part of the basin itself, as proved by numerous borings at different points, and by the actual workings of the mines. The coal is reached by vertical shafts varying from 180 to 300 feet in depth.

#### GEOLOGY OF THE BASIN.

On examining the bluffs forming the southern and southeastern banks of Coal Creek, we find them to consist of heavy-bedded sandstones, averaging from 60 to 100 feet thick. On the bluffs these sandstones are nearly horizontal. Resting on them, and overlaid by a few feet of drab shale, is a coal seam thirteen inches thick, forming the top of the bluff; from this point we look down on the flat coal basin, Coal Creek flowing beneath us along the base of the bluff. About 2,000 feet from this, on the open flat, is the opening of the new slope of the Louisville-Welch mine. The coal there comes up to the surface and dips down into the basin in a northerly direction, at an angle at first of 52 degrees. This dip gradually diminishes with depth until at about 300 feet below the surface it is only 3 degrees to the southeast, rising again gently toward the north.

The sandstone found below the coal in this opening, together with the little 13 inch seam above the sandstone, correspond to the partial section exposed on the bluffs 100 feet above the basin. It is evident then that these two separated outcrops were once connected by a fold, which by tension broke, and a "fault" or "slip" was the result. The uplifted or constant side of this fault is represented by the steep bluff forming the bank of Coal Creek; the fallen block of ground, by the flat depressed area of the Louisville basin.



The actual line of fracture is approximately represented by the course of the stream, limiting the coal area in a southeast direction. Hence all tunnels driven in the direction of the creek will, on nearing the stream, be found to abruptly terminate against a wall of sandstone. The presence of this fault does not prevent the existence of other coal areas across the creek to the south and southeast.

I am told that the coal in that direction, bordering the creek, is much broken up and even stands vertically, as might be the case if the line of fault follows the course we have surmised.

The strata underlying the basin are not found by underground development to be as level and undisturbed as the appearance on the surface might imply. The average dip of the basin strata is from 3 to 5 degrees to the southeast, but this uniformity is occasionally disturbed by a series of gentle "rolls" or undulations, whose axes are doubtless parallel to the general line of the fault, the natural result of compression, exerted from either side of the basin, from southeast to northwest.

The amount of slip of the fault is from 350 to 400 feet, measuring from the outcrop of the little 13-inch seam exposed near the top of the bluffs, to the position of the same as revealed in the workings of the mine in the depths of the basin.

But one important coal seam is worked, varying in thickness in different parts of the field, from 7 to 14 feet. The thickest portion, so far as at present known, appears to lie toward the eastern limit of the basin, in the vicinity of the village of Lafayette. Borings from the surface downward for some 300 feet have encountered several unimportant seams, until the main seam has been reached, below which is an interval of shale and sandstone, and then the 13-inch seam alluded to as occurring on top of the bluffs, is met with, below this again is the basal heavy-bedded sandstone, 100 or more feet thick. This basal sandstone is the extreme lower limit of the coal series. No coal, of importance, throughout the State has been found below this well-known massive yellow sandstone, the coal miner's "bed-rock." It is called, by geologists, the "Halymenites" or "Fucoidal" sandstone, from the frequent presence of the fossil casts of what is supposed to be a seaweed or Fucoid, called Halymenites. The



impressions are pitted and are such as a corncob might have left, a useful fossil-sign for the miner, showing him the limit to his work of boring.

Coal in Colorado is generally found above this massive sandstone, rarely below it. For below it lies a thickness of some 2,000 feet or more of barren shales containing sea shells, and called the Colorado group. As this represents the bed of the Cretaceous *sea*, it is not a likely set of strata in which to find remains of *land* plants and vegetation that originated the coal beds. We may here add, that a bore, a mile or more deep below the present well-known Laramie coal horizon, would result in discovering no more coal than we actually do find, so generally near the surface, for the underlying strata show very clearly where they are upturned near the flanks of the mountains in admirable sections, that no coal exists for thousands of feet between the Laramie coal horizon and the granite bed-rock.

#### COAL OPENINGS.

The signs that led the prospectors to bore for coal in the basin were the outcrops in plain view on the bluffs. The old Welch mine about half a mile east of Louisville has a shaft down 180 feet, which struck the main seam 8 to 10 feet thick. This was developed for some years over a large underground area by the usual "room and pillar" system, and thousands of tons of coal were extracted. "Gob" fires breaking out, accompanied by a series of strikes, (the latter appearing to constitute an essential element in the atmosphere of these Boulder County coal districts,) the mine was abandoned and flooded with water. The plant, much enlarged, together with a new outfit of some of the most powerful mining machinery in the country, was moved to a new site on the field, about a quarter of a mile east of the old workings, and nearer the centre of the basin. To determine a suitable location for the new openings and to prove the continuity of the coal, two borings were made 1,800 feet apart. At both places the bores recorded from 7 to 10 feet of coal at about 200 feet below the surface. The surface of the prairie being flat and undisturbed between the two borings, it was naturally assumed that the strata and the coal in the same interval below would be correspondingly



undisturbed and uniform in thickness and character. So without much further prospecting the works were moved to a site half-way between the two borings, and a shaft was let down, which, contrary to expectations, happened to strike a locally poor spot in the coal field, where the coal was split up by belts of shale and where occurred one of these "rolls" we have mentioned, as probably traversing the basin in parallel systems. The shaft appears to have struck this roll on the top of the arch, and good coal is hardly to be expected until they get off the axis on either side, that is, towards the north or south.

"Rolls" are common in our Colorado coal fields<sup>\*</sup> and the point of their occurrence is characterized by a local admixture of shale and "bone" with the coal, and by a thinning of the coal and corresponding thickening or bulging in of the over or underlying sandstone or shale. The cause of "rolls" may be two-fold: first, that while the coal beds were forming in a marsh, or after they had formed and were consolidated, they were subject to erosion by streamlets or periodical freshets, which hollowed out channels in the coal and afterwards filled the depression with sand or mud, which subsequently became sandstone or shale; secondly, that the "rolls" may be minor folds or undulating strata resulting from lateral compression in the general uplift. The coal is usually thinnest along the top or axis of a "roll" and thickens in the trough or either side of it. We can easily understand that intrusions of shale and slate might occur locally more abundantly in certain parts of a coal basin than in others, and locally a coal seam may be split up and rendered valueless by belts of slate at one point, while but a few yards off the same seam may be almost pure. Not more than 2,000 feet from this local shaly "roll" the bore shows 10 feet of good solid coal. Again, two miles southeast of it, at the Lafayette mines, we have 14 feet of coal absolutely free from shale or other partings. In the great coal seam of Trinidad we find the same phenomena as at Louisville, in various parts of the field and often in localities not far distant from one another. It is clear that the persistency, continuity in thickness and character of the seam cannot be relied upon for any great distance over a coal field, and that prospecting by boring should generally be kept up ahead of the underground



development. It seems even advisable to put down a bore exactly on the point upon which we think of shafting and erecting works, no matter how undisturbed and uniform the surface signs may appear, nor how continuous the thickness of coal may be in other parts of the field.

#### NEW SLOPE ON THE WELCH MINE PROPERTY.

A promising opening has been made about 800 yards to the southeast of the old abandoned Welch shaft and about 2,000 feet from the new works. It is at the point where the coal comes to the surface by reason of the fold and fault I have mentioned. The coal is opened up by an incline on the seam of 52 degrees dip for 100 feet, this dip becomes less and less as we descend, till at 150 feet it is about 30 degrees; at 250, 10 degrees; after that the coal follows the general dip of the basin, of three degrees to the southeast. Across the basin to the northwest the coal strata appear to rise gently; the coal also is said to thin somewhat in that direction. The coal seam in this slope is eight feet thick, of good quality and free from any important seams of shale or bone. Below the main coal seam is about 14 feet of yellow sandstone, then the 13-inch seam, and below this for an undetermined depth is basal *Halymenites* sandstone.

#### THE LAFAYETTE COAL MINES.

From the Welch-Louisville mines we follow down the basin in an easterly direction for two miles and arrive at the coal village of Lafayette, which numbers about 100 houses. This village has sprung up within a few months around three recently opened coal mines, viz: the Mitchell, Cannon and Simpson mines, whose shafts find the coal seam 14 feet thick at a depth of 300 feet below the surface. The coal is absolutely free from any parting of clay, shale or bone.

These three mines being but a comparatively short distance apart, one mine may be considered as typical of the whole. We chose the Simpson for examination. The coal is soft, easily worked by room and pillar, and the thickness of the seam permits



the leaving of four feet of coal to protect the roof, which is generally poor in this region, consisting of shale, or treacherous sandstone. This leaves a height of ten feet clear for rooms and entries. The face and end structure is well shown in the cleavage of the coal, the faces pointing north and south, the ends east and west. This is one of the finest looking coal seams we have seen on the eastern slope of the Front range. The coal, though good for general purposes, will not coke. The Harrison coal cutting machine is used in the Simpson, the Leg cutter in the Welch mine. In the Welch mine is some of the heaviest machinery for working air compressors to be found in Colorado.

The Lafayette mines seem to have struck that part of the basin where the coal is thickest.

If we consider that coal was formed in marshy basins undergoing a slow subsidence, we may suppose that portions of such basins would be relatively or locally deeper than others, so if a deep, thick portion of a coal field is found, on general principles we may expect it to gradually thin out all around this central thick portion.

In this case it may be found thinning out to the north, but on the south and southeast sides, not very far from the present workings, the seam will probably be cut off by the fault, which follows the course of Coal Creek. It diminishes also in thickness toward the west at Louisville, where the Welch mine shows it to be but eight or ten feet thick. We are told there is a tendency to thin out toward the northwest also.

Analysis of the coal of the Simpson mine, at Lafayette, by Prof. Regis Chauvenet.

Water . . . . .	12.01
Volatile matter . . . . .	35.19
Fixed carbon . . . . .	46.24
Ash . . . . .	6.56
	<hr/>
	100.00
Sulphur . . . . .	1.00

#### THE MARSHALL COAL FIELD.

The coal area is about ten miles northwest of Louisville and six miles south of Boulder. A branch railroad connects it with



Louisville. The railroad cuttings on the way expose, at several points, partial sections of the Laramie strata, till the road emerges from the bluffs into a flat, depressed area, the topography of which is the result partly of faulting, partly of erosion. The bluffs on the southeast side of the basin owe their steep, elevated position to their being the risen side of a fault, which passes through the length of the entire area. The flat, meadow-like portion, at the foot of this, which is occupied by the village and some of the principal workings, is the fallen side of the fault. The rolling rounded bluff, or mesa, on the north side and in the foreground of the illustration, Plate IV, which shows several curvilinear and flattish outcrops of sandstone and some coal exposures, owes its shape to folding, and possibly to faulting. Mr. Eldridge considers this mesa a good example of torsional strains, with divergent faults, and accompanying folds. The line of the main fault passes along the base of the bluffs, in the direction apparently marked by the course of a small stream, and very nearly by that of the railroad track.

Mr. Eldridge says, concerning this faulted district: "The triangular area between Coal Creek, the mountains, and an east and west line a little north of Boulder Creek, is characterized by faultings. Its component lines of dislocation are grouped in such a manner as to suggest a series of curvilinear faults concentrically arranged, extending over nearly the quadrant of a circle. It is probable, however, that the resultant curves are each composed of three distinct linear faults, the southern trending N. 60 E., the middle N. 30 E., and the northern a few degrees west of north."

In immediate proximity to the line of fault, the strata of the fallen and foot-wall block of ground has at the edge been dragged upward and bent back upon itself, in its process of slipping against the face of the uplifted block. This reversal of strata is shown in a little hog-back close to the fault line, marked K in the illustration. The strata dip about 50 degrees to the south, while a few feet from them the heavy-bedded sandstone of the bluff, forming an abrupt cliff, dips only 5 degrees in the same direction. Such a sudden increase of dip of strata so close to one another is a sure indication of a fault. The fault is encountered



in the workings of the mines, the coal being abruptly cut off by a wall of sandstone throughout the length of the field, as it approaches the foot of the bluffs which form the southern boundary of the basin. On ascending the bluff, the existence of the fault is further shown by the fact that the strata composing the ridge are duplicates of those found 300 feet deep in the workings of the mine in the flat, meadow portion. There are two or three principal coal seams in this field, separated from one another by a few feet of sandstone, and underlaid by the massive yellow "fucoidal" sandstone, which, as we have said, forms the base of the series. The idea that there were four or more important coal seams on the property arose from not recognizing the duplication of strata and seams caused by the faulting. The upper seam is 8 to 9 feet thick, the lower about 4 feet. The upper one is that which is principally worked.

On the face of the bluff the coal outcrop shows evidence of having been burnt, probably at a very early date. The surrounding sandstone is reddened, and the shale and clay reduced to a hard red jasper. The coal of this area seems very liable to spontaneous combustion, for portions of the field and of the old workings have been burning for many years. Some of the workings on the north-west side, from which the pillars were withdrawn, collapsed, leaving wide open fissures and cracks in the upper surface. Soon after this, smoke was seen issuing from the ground, and that portion of the field is now in a complete state of combustion as shown in the illustration. This long continued combustion must have exhausted a vast amount of coal over a considerable portion of the field. As we follow the coal strata along the bluffs toward the west, they come abruptly to an end on the edge of a basin-like hollow of erosion between them and the lower geological strata of the foothills and hog-backs flanking the mountains. No coal is found for an interval of three miles between this point and the range. Similarly about a quarter of a mile to the north the coal area is cut off by the erosion of South Boulder Creek, and terminates in a high bank above that stream. No coal has been found for some miles to the northwest in the direction of Boulder city. To the southwest the workable coal found in the bluffs is restricted by a

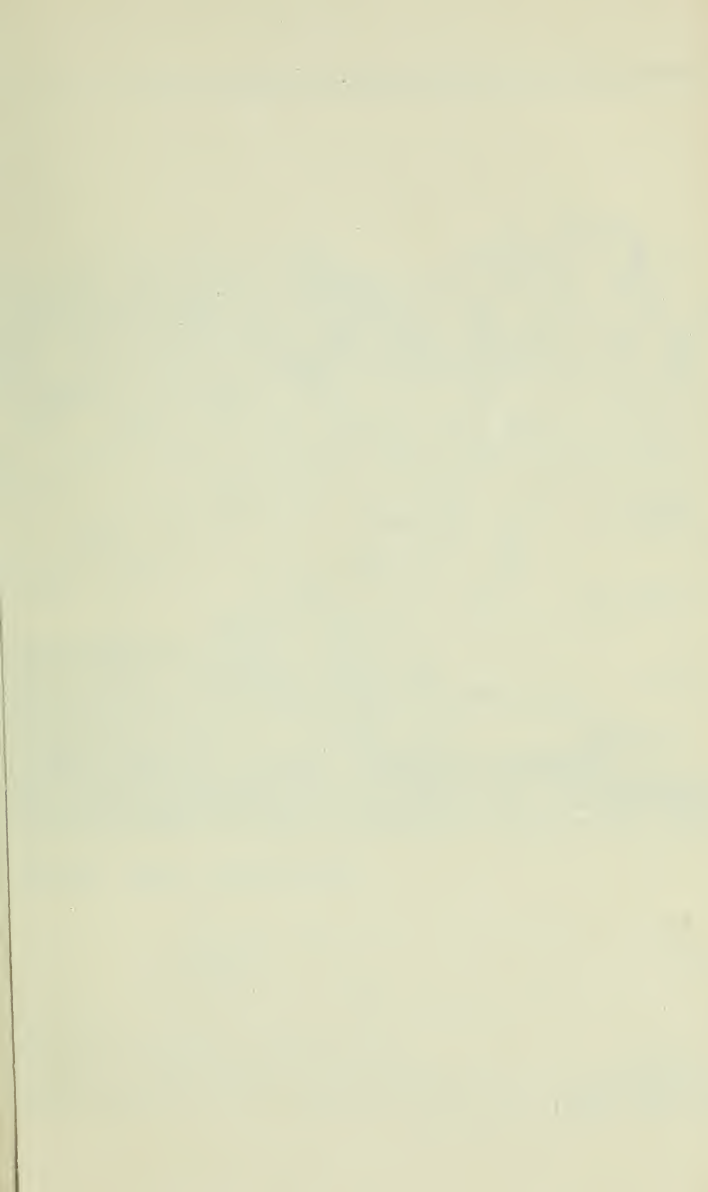


faulted and broken-up area in the neighborhood of Coal Creek. This coal area is therefore circumscribed on three sides by natural limits. On the east, however, (since as we presume it passes under the prairie and is brought to light by erosion or faulting far on the plains, as at Erie or Louisville,) there appears no such definite limit. Coal might if properly looked for be found, we think, at other points between Marshall and Louisville, at varying depths probably not exceeding 500 feet.

The workable coal area is limited on three sides to about a square mile, on the fourth side as we have said there appears to be no definite limit. A good deal of this area has been worked out in past years; enough remains, however, for some years to come. It is an old field with a portion worked out, a portion burnt out, and a good deal of coal still left. The dip of the strata and the faulting, combined with surface erosion, have brought the coal nearer to the surface on the western and north-western limits of the field, it being there only 30 to 50 feet deep. Some of the coal in this portion is not sufficiently good for market, the remainder is of good quality. The workings both old and new, are quite numerous; in the flat portion, the new workings consist of incline shafts reaching the coal at a depth of about 90 feet from the surface, from these radiate series of entries and rooms following the average dip of five degrees; in this way a large area has been undermined. The elevated area is worked by running tunnels at a slight angle up into the face of the bluff till the coal is reached and followed down on its dip toward the south. The seam worked is generally about eight feet thick with local variations. It is but little troubled by seams of shale or bone. The coal, though not coking, is good for general purposes.

The strata immediately above the coal seam consist of shale and thin-bedded sandstone for about forty feet. On some of the sandstones are beautiful impressions of ripple marks often incrustated by a thin layer of iron-oxide. The sandstones are characterized by a net-work of fossil mud-cracks, caused by the shrinking of the mud in the process of drying and consolidation in the gradual change of the ancient coal swamp to its present stony condition. The original cracks were filled by some harder









A.A. LARAMIE LIMST. B.B. COAL ON FIRE C.C. N. PARTIAL AREA FOLDED. D.D. N. WESTERN LIMIT OF COAL. E.E. S. WESTERN LIMIT OF COAL. F.F. QUATERNARY LAKE TERRACES. G.G. TRIASSIC & JURASSIC. H.H. SANDSTONE UNFOLDED ON GRANITE. I.I. ARCHAEAN GRANITE. J.J. LONGA PARK DISTANT. K.K. BOULDER CITY.

# MARSHALL COAL MINES NEAR BOULDER.



NORTH SOUTH  
 NEW WELLS MINE  
 LARAMIE CHETA  
 MARSHALL COAL FIELD  
 LARAMIE COAL GROUP  
 FOX HILLS  
 AND  
 COLORADO CRETACEOUS  
 JURASSIC TRIASSIC  
 ARCHAEAN  
 DIAGRAM TO ILLUSTRATE STRUCTURE OF THE LOUISVILLE BASIN.

Engraved by American Bank Note Co., New York.

Engraved by American Bank Note Co., New York.



quartzitic material often combined with iron-oxide. Surface erosion, by removing the softer portion of the sandstone has left these harder seams in prominent relief, giving a very rugged aspect to the rocks. These sandstones are full of concretions of iron which often drop out and cover the ground with nodules, showing a cup and ball structure. Indications of ancient terrestrial vegetation are common, in the form of leaf impressions and petrified stumps. At the eastern end of the area the railroad cutting exposes a belt of five feet of calcareous sandstone composed largely of fossil oyster-shells. These lie a short distance above the "fucoidal" sandstone, and about forty feet below a small coal seam.

#### DESCRIPTION OF GEOLOGICAL SECTION, PLATE IV.

The relation of these Laramie coal-bearing strata to the Cretaceous, Jurassic, and Triassic periods lying geologically below them is well seen from the western end of the area, and is also shown in the illustration. To the West we have the Archean granites and gneisses of the mountain range. Resting upon them at a steep angle is a great thickness of red Triassic sandstone, partially metamorphosed, followed by the Jurassic variegated shales and limestones, and by the hard white Dakota sandstones. The fine conglomerate forming the base of this latter group has been metamorphosed into an adamantine pudding-stone, pebbles of which are profusely scattered among the surrounding drift. The sandstones of the Dakota have also been metamorphosed into hard vitreous quartzites. Other gneissic and quartzitic pebbles in the drift, showing by patches of quartz that they were once conglomerates, appear to have come from some obscure, lower and metamorphosed horizon lying between the Trias and the granite and may be of ancient Paleozoic origin. The uplifted strata of the various groups offer a most picturesque appearance from South Boulder to North Boulder cañon. Gigantic, massive sheets of strata are uplifted to a height of some 2,000 feet above the valley, and carved by numerous chasms, into pinnacles and cathedral spires. The heat produced by the friction of this extreme uplift of these thick masses has doubtless caused the partial metamorphism we find in them. On the back



of these great hog-backs, occupying an humbler position, are the marine shales of the Fox Hills, Cretaceous and Colorado group, a thousand or more feet in thickness. These are similarly uplifted, but owing to their softness have been degraded to a lower level. Above them in order follow the shaley beds and sandstones of the Laramie group. These, as they approach the mountain border, partook of the same uplift, but the whole of the uptilted part has been removed, and eroded back, till the nearly level portion which underlies the prairie has been left in the position we find it, forming the bluffs and flat area of the Marshall coal field, and dipping to the southeast only five degrees. The line of the fault passing through the coal fields, points in the direction of the deep narrow gash in the mountains caused by South Boulder cañon, suggesting a common origin for both cañon and fault, along one line of fracture. Remarkable terraces of drift material are seen resting high up against the flanks of the mountains, lying unconformably upon the tops of the various upturned strata. These appear to mark the level of certain great lakes that at one time covered a large area of this region. The different levels of these terraces mark the gradual recession and pauses of the waters of these lakes and their subsequent erosion by post-glacial streams.



## CHAPTER V.

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Cañon City Area.







## Chapter V.

### CAÑON CITY AREA.

From the Denver basin going southward we come to what we may designate as the Cañon City area, embracing that section of country lying between the Divide on the north and the Arkansas river on the south, and between the Colorado range on the west and an indefinite line of the prairie to the east; in this area are the towns of Colorado Springs, Pueblo and Cañon City.

#### GEOLOGY.

The geology of this district has many features in common with the Denver basin. The sedimentary strata are uplifted to verticality along the mountain border; the lower section of these is formed of Paleozoic rocks of the Carboniferous and Silurian periods, resting directly upon the granite; the upper of Mesozoic strata. Near the northern part the uplifted beds are obscured by being overlaid by the horizontal Monument creek Tertiary lake beds to a depth of about 1,000 feet, but south of this the erosion has removed these beds over a wide area back to the Austin bluffs, some miles out on the prairie east of Colorado Springs, and exposed the underlying strata, so that from Colorado Springs along the road to Manitou we have a grand complete section of the earth's crust from the Tertiary down to the Archean granite. The uplifted strata are well seen in the celebrated Garden of the Gods and between that point and the granite back of Manitou. They consist of Fox hill shales, Colorado limestone with its characteristic *Inocerami* shells, Dakota sandstone, Gypsiferous Jurassic limestone, and red Triassic conglomerate, and below these, variegated sandstones and limestones of the Carboniferous, red limestones and dark reddish brown and olive green sandstones of the Silurian, the latter forming the walls of the Ute and Williams cañons at Manitou, until finally we reach the Archean granite and gneiss of which Pike's Peak may be taken as a type.



The peculiar vertical and overturned dips of the strata may be explained on the "S" fold theory we have already discussed at Golden. The Laramie group does not occur prominently in this section, but about ten miles east of Colorado Springs, either by erosion or a fold, it is brought to the surface, exposing coal seams which have been worked for some years at Franceville, along the line of the Fort Worth railroad.

#### OIL WELLS.

From Colorado Springs south we enter a wide bay in the mountain outline, dividing the Colorado from the Greenhorn range. Through the centre of this the Arkansas river flows, issuing from its cañon in the granite. The strata in this bay consist of horizontal table lands of the Colorado and Fox-hill group. In the latter, at Florence, oil is found by boring. At 1,225 feet the first oil sand was struck, followed by an explosion of gas. The wells have been continued to 1,400 and 1,500 feet, bringing up, at the latter depth, water 90° F. The location of the wells is about the center of the basin, which is formed by the rocks in the vicinity of the ranges tipping up in a semicircle around it at an angle of 45 to 75 degrees. The geological position of the oil wells is shown by the presence of a table land called Castle Rock, a short distance from them, which is capped by the "fucoidal" sandstone, which immediately underlies the coal, hence the oil-sand lies about 1,500 feet below the coal in the Fox-hill shales,

#### THE COAL FIELD.

The table lands and bluffs of sandstone on the south side of the river, between Florence and Cañon City, contain the Cañon City coal field, a basin isolated by erosion from the main coal field along the range. It is an irregular oval, about twelve miles long by two miles broad, consisting of heavy beds of sandstone, with shales and coal seams resting on the basal "fucoidal" sandstone, and that on the Fox-hill shales. The coal outcrops along the exposed edges of the field, which is in the form of a synclinal fold, as the strata are tipped up toward the west by the range, and dip in toward the center from the east, involving a



second anti-clinal before they can again conform to the horizontal strata of the prairie. This is one of those secondary rolls or undulations often observed along the flanks of the mountains.

The coal-bearing formation is about 700 feet thick, consisting of sandstone and shales, containing several small coal seams of unworkable size, followed below by one from three to five feet thick, developed by the Colorado Coal and Iron Co. and the Santa Fe R. R. Co. In the valley of Oak Creek, at the Santa Fe mines, we descend a shaft 300 feet deep, and at the bottom find the seam three feet wide and nearly horizontal. The tunnels are low and cramped and the air somewhat warm and stifling. The mine is developed by the "long wall" system. The pressure of the heavy sandstones above is utilized in breaking down the coal, which cracks off with a report like that of a pistol. The coal gives off a good deal of noxious gas, resulting sometime since in a fatal accident. In places (where it is safe to do so), the presence of gas can be shown by applying a naked lamp to the crevices whence it exudes, when it ignites with a vivid flash. The ventilation is by fans and the hoisting is through the shaft. In digging this shaft 312 feet, as many as nine small coal seams were met with before the present workable one of three feet was encountered. Although the seam was so narrow, the coal is of sufficiently good quality to warrant much labor in developing it. It is to be observed that, as at Golden, and generally along the foot-hills, it is the lowest seam in the formation that is workable.

In the same field the Colorado Coal and Iron Company have for many years been working their mine on Coal Creek, a branch railway line running from Florence to the mine and village. As we ascend the creek we notice the drab shales of the Fox-hills Cretaceous, curiously sculptured by rain, and revealing their marine origin by numerous fossil shells; further up, the shales are capped by the yellow "fucoïdal" sandstone, with its characteristic impressions of seaweed (*Halymenites*) showing that we are approaching the limit of the marine formations, and soon, above them, we find evidences of land, in fossil plants and leaves of trees imbedded in the sandstone, quickly followed by a seam of coal 5 feet thick dipping westerly into the hillside at an angle of



5 degrees. Down this dip a slope is run at the Coal Creek mine, from which tunnels and rooms are run off on either side. The developments extend underground over a mile in length, and half a mile in breadth. Four feet of the coal is worked, and the remaining foot, which is separated by a clay seam, is left to strengthen the roof. The holes for blasting are driven by hand-boring drills, the rest of the work is by pick and shovel. Transportation is by mules from the side levels to the incline, when a steam engine, with wire cable, hauls about sixteen cars at a time up the slope. Ventilation is by air shaft and fan. About 130 men are employed at this mine, and an equal number on Oak Creek.

The seam is free from slate or other impurities. The coal of this area, though long celebrated through the State for its excellent qualities for domestic and blacksmithing purposes, is beyond the coking line, which we find restricted to the Trinidad region.

Below the coal, the massive "fucoidal" sandstone is extensively quarried for building stone.

#### DINOSAUR DISCOVERIES AND OIL WELL ON OIL CREEK.

About ten miles to the north of Cañon City is a small park through which runs Oil Creek. This park is celebrated for two things, both perhaps having some obscure relation to one another—the discovery of oil in it many years ago, and in later years of enormous saurian remains, similar in many respects to those at Morrison. The rocks of the park consist principally of red Triassic sandstones overlaid by variegated shales and clays of the Jurassic, capped by the Dakota sandstone, forming a shallow, synclinal basin, the strata in the centre being horizontal. These have been cut by erosion into towers, castle rocks and other picturesque forms, a romantic spot suitable for sepulchres of the mighty saurians whose bones repose there. At the time of our visit Professor Marsh's party were excavating the skeleton of a gigantic dinosaur from the solid sandstone; the black ends of a huge thigh bone, six feet long and proportionately thick, were protruding from the rock, while a row of equally huge vertebra (part of the animal's tail that had been exhumed) were lying on the bluff ready for packing up. Quite a number of different



animals of the saurian family have been obtained from the locality by Professors Marsh and Cope. Upon these *Atlantosaurus* beds in 1862 a well was put down in search of oil, traces of which had been found floating as an iridescent scum upon the waters of the creek, and at 100 feet several barrels were obtained of a thick lubricating oil, of a dark, blackish green color, 42 degrees Baume. Thus it appears there is a Jurassic oil horizon at least 3,000 feet below that found at Florence in the Cretaceous. If the oil reservoir is in these saurian beds, it has been suggested that its origin may have been from the organic portions of those monsters, preserved as hydrocarbons, for oil is admitted to result from distillation of animal and vegetable remains such as are found fossilized in the rocks. The ultimate source of this oil, and perhaps even that at Florence, may arise from a still lower horizon, such as that of the Carboniferous and Silurian limestones which outcrop on the edge of the Grand Cañon. The oil wells in the neighborhood of Cañon City have been working now for some years with fair results and have become part of the industries of the State. Just west of the city the Colorado limestone, full of large *inoceramus* shells, is extensively quarried by the convicts of the penitentiary. At the base of the Dakota hogback, back of it, a number of pleasant tasting carbonated springs issue. At the mouth of the cañon between the Dakota and the granite are hogbacks of some 3,000 feet of Jurassic, Triassic, Carboniferous and Silurian sandstones and limestones of a reddish color. In the Silurian we find fragments of fossil corals and shells; at its juncture with the granite, a hot saline spring issues, the water of which is 90 degrees F., and contains common salt, with a percentage of carbonate of soda; a bath house is erected over the springs. From this point we enter the Grand Cañon of the Arkansas, cloven by water 2,000 feet deep, through solid granite, gneiss and hornblendic rock.







## CHAPTER VI.

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Trinidad, or Raton Coal Fields.











# MAP OF TRINIDAD REGION, after Hayden's Survey



COLORADO GROUP



LOWER COAL HORIZON.



UPPER COAL HORIZON.

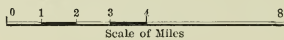
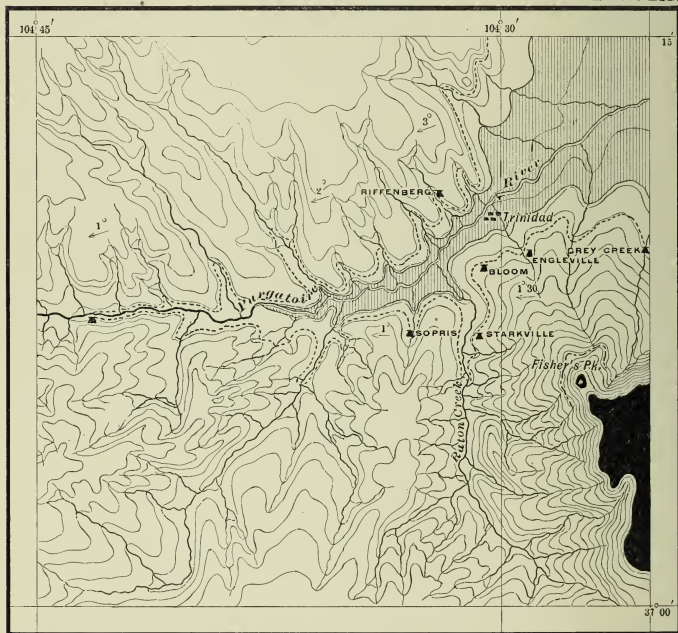


COAL-OPENINGS.



BASALTIC CAP.

*Plate LX.*





## Chapter VI.

### THE TRINIDAD, OR RATON COAL FIELDS.

After leaving the Cañon City district, there is an interval of some miles between the Arkansas and Huerfano Rivers, in which no coal of importance has so far been discovered. A few miles, however, below the Huerfano River, is one of the largest and most important coal fields east of the Rocky Mountain range, covering, not only a large portion of Southeastern Colorado, but extending for many hundreds of square miles into New Mexico, and occupying a large part of the Maxwell Grant. We call this the Trinidad Coal Fields, from the name of that important city located upon it, in the extreme southern limit of the State. The table-lands which contain the coal, belong, properly, to what are called the Raton Mountains, the field being by some called the Raton Coal Field. The town of Raton is situated on the field, south of the Colorado Line, in New Mexico.

The area occupied by this great field is about 750 square miles, including the portions both in Colorado and New Mexico, extending on the north from the Huerfano River, in Colorado, to the Cimarron River, in New Mexico. It is bounded on the west by the Sangre de Christo range, and on the east by the erosion of the prairie, in a line approximately corresponding with that of the Rio Grande and Fort Worth Railways.

#### TOPOGRAPHICAL AND GEOLOGICAL FEATURES.

The main feature of this region is a long, wide plateau, of a very uniform appearance and structure, running for many miles along the flanks of the mountain ranges and extending out on to the prairie border, where it is abruptly cut off, showing for many miles a steep, monotonous wall of yellow sandstone, underlaid by dark gray shales, about 300 to 500 feet high, indented here and there by sharp ravines, from which small streams issue, till we reach the Purgatoire River, upon whose banks the town of Trinidad



is situated. The plateaus then assume a much loftier aspect, forming a table-land, called the Chicorica mesa, 2,000 feet high above the river bed. The top of the mesa is capped by basaltic lava, which has preserved the full thickness of the Laramie coal-bearing group, part of which has been removed by erosion from the greater portion of the rest of the field.

A section of this plateau shows three important divisions :

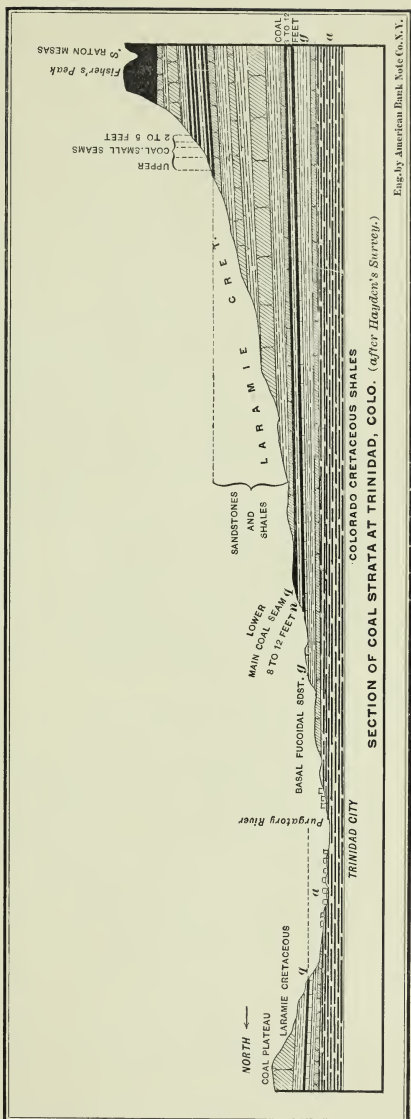
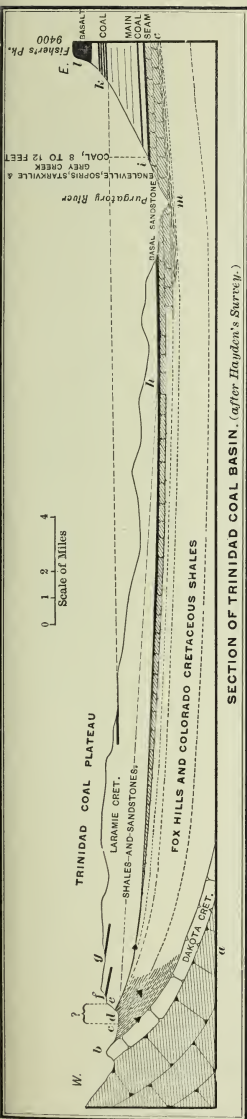
(1st.) At the base is an unknown, but probably great thickness of the marine Cretaceous shales of the Fox-hills Group, of a drab gray color, containing many marine fossil shells and concretions of clay ironstones.

(2d.) These are capped by the yellow fucoidal sandstone, which in this region is very conspicuous from its massive character, forming a distinct line of yellow rock from 50 to 100 feet thick, traceable all over the region, and marking off the downward limit of the coal-bearing series which lies immediately above it, from the non coal-bearing shales which lie below it. The seaweed impressions (halymenites) are very common and distinct, and the sandstone is extensively quarried for building stone and grindstones, for which purpose it is one of the best in the state.

(3d.) Between 50 and 100 feet above this, the coal seams of the Laramie group commence. The first seam is usually from two to four feet thick, and not generally worked in Colorado. A few feet above this is the main or Trinidad seam from six to fourteen feet thick, and the one generally worked. Numerous small seams and indications of coal, with intervals of sandstone and shale between them, occur to the top of the mountain, and about 800 feet above the lower seams, a cluster of small seams occur which are in some places of workable thickness. Throughout the entire Laramie group of 1,800 feet thickness, fossil-plants and thin seams of lignite are common. Wheeler's survey counts about 32 seams of coal, both small and great, in this mesa, making about 105 feet of coal altogether, not more than 20 feet on an average being workable. Prof. van Diest estimates the amount of workable coal contained in the entire field at 10,000,000,000 tons.

The lower and main seams appear to be pretty constant over the greater part of the field, though varying from place to place











in thickness and quality. In fact, this variability is a notable feature of this, as well as of other large coal fields. Thus, at Engleville the Trinidad seam is twelve feet thick. Five miles southwest of it, at Starkville, it is only six feet; and eight miles east, at Gray Creek, it is eight feet, and is in places split up by partings into several seams. Over the border, in New Mexico, the Trinidad bed is only five feet, occurring locally on Crow Creek, and is very shaly, while the Dillon bed, which lies below the Trinidad, and in Colorado is seldom of workable size, is there five feet, and extends over much of that region. Professor Van Diest enumerates twelve coal beds in New Mexico, varying from three to five feet, aggregating forty-five feet of coal, and remarks "that all these beds do not extend over the whole of the Maxwell Grant, the lowest beds, as in Colorado, having the greatest extent, the higher beds being much limited by erosion." The thickest and probably central portion of the coal fields seems to lie under Fisher's Peak.

The coal field was once of far greater proportions than at present, having been limited especially to the east by extensive erosion. It was doubtless connected with the Cañon field to the north, as that was once with the fields of Northern Colorado, and those again with the Laramie fields of Wyoming. To the south, also, below the Maxwell Grant, it had doubtless a much larger extent.

The coal plateau is not a flat table land, but a shallow trough, one side of which tips up at a steep angle toward the west, in the neighborhood of the Spanish peaks and the main range, by the elevation of those mountains, and at a gentler angle in an opposite direction toward the east, where it is cut off by erosion. The river Purgatoire occupies, approximately, the center of the trough so formed. In the New Mexico region the same folding is observable, and it was this folding which has brought the coal above the surface within easy reach of development by tunnels without the need of deep shafts. Besides these principal folds, several minor undulations of the strata occur locally.

#### VOLCANIC ROCKS.

Another striking feature of this region is the presence of volcanic rocks, erupted through the coal plateau. The plateaus are



penetrated by a network of lava dykes, and in some cases, as at Fisher's Peak, part of the flow that issued from these dykes still remains and protects the coal series over a large area from erosion. In other cases the lava-cap has been removed, and nothing but the dykes or channel sources remain. One of the "foci" of these eruptions, which occurred, probably, in tertiary times, long after the coal strata were deposited, is in the neighborhood of the Spanish Peaks and adjacent (La Veta, Sheep and Silver) mountains, near the northwestern portion of the district. From these great "laccolites" or subterranean reservoirs of volcanic rock, an immense number of dykes radiate for miles over the adjacent country. The influence of the heat from these volcanic outbursts has been felt by the coal, large areas of which have been changed from the lignite of the north into a fine bituminous, and also into a good coking coal, and locally, in close proximity to some of the dykes, where the heat was greatest, into a natural coke, or even into an impure graphite. The coking coal area appears to be limited in Colorado to the southern portion of the field, from the Purgatoire River to the Chicosa; the coal north of that, though caking, will not coke.

Near the northern portion of the area, between the Huerfano River and the Spanish peaks, Mr. R. C. Hills has discovered extensive tertiary lake-beds of great thickness, that originally covered a large portion of the Laramie coal plateau, and lie unconformably with the dip of the latter. In the sandstones and shales some fossil turtles and other remains of Tertiary origin were found. The dykes and laccolites of the Spanish peaks are surrounded by a great thickness of this formation. The rest of the geology and stratification of the region is similar in many respects to that already described further north from the Cretaceous to the Carboniferous, which latter period, according to Dr. Endlich, rests directly upon the Archean granite, and with the other upturned Mesozoic strata, forms the flanks of the Sangre de Cristo range, to the west of the coal plateau.

The Trinidad region embraces the Walsenburg district on the north, including the Walsenburg, Pictou and Rouse mines. The Santa Clara mines are a few miles further south, and next to them are the Chicosa mines, including the Victor and Forbes



mines, about fifteen miles from Trinidad; lastly, the mines around the base of Fisher's Peak in the neighborhood of Trinidad. These are the Gray Creek mines, the El Moro mines at Engleville close to the city, the Trinidad mines at Starkville, six miles further to the south, and the Sopris mines about five miles southwest, near the river, besides all which there are several small mines opened by private parties. Just over the Colorado border are the Raton coal mines, tributary both to Colorado and New Mexico.

#### EL MORO MINES AT ENGLEVILLE, C. C. & I. CO.

These mines, located at the base of Fisher's Peak, about four miles southeast of Trinidad, have been in successful operation for upwards of twelve years, and during that time have mined out some square miles of coal, and their developments are to be reckoned by miles in length rather than by feet, as in the younger mines. There are thirteen miles of track now in this mine, a sketch of which may be seen in Plate VIII.

The developments are by parallell drifts, one of which is 6,600 feet long, run into the base of the mountain, and working to the raise on the gentle dip of the nearly horizontal strata, so that the laden cars descend easily to the openings. The mine is developed by the room and pillar system. From the main entries double entries are run off at right angles, and rooms 20 by 300 feet branch off from these. The rooms work on the "face" of the coal, the main entries being driven on the "butts." After the rooms are worked out the coal pillars are cautiously removed and the roof allowed to cave in. As the seam is very thick, being from nine to twelve feet, from two to four feet of coal is left in the roof, which is much safer and stronger than the ordinary shale or sandstone, so fertile in accidents; little timber is consequently needed in the mine. A few "rolls" occur here and there, pinching the coal slightly, also some "nigger heads" or concretions of shale or iron pyrites are met with occasionally, and a few thin partings of bone or shale at irregular intervals, near the top, middle or bottom of the seam. It is these clay partings which cannot be separated from the coal, that give the rather high per cent. of "ash" in the analysis of the coke.



It will be observed that all these mines are opened only within easy access, or directly along the lines of the railroad routes, the centre of the plateau and the western upturned portion being at present undeveloped, though doubtless some of it has been taken up by speculators.

Government sells coal land at \$20 per acre when within fifteen miles of the railroad, and at \$10 per acre outside of those limits, and as one individual can take up but 160 acres, it is necessary for a company wishing to acquire a large tract to buy out several individual claimants.

About one-half of the coal, including slack and screenings, is turned into coke at El Moro and shipped to the Bessemer works at Pueblo, and to the various smelting establishments along the line of the Rio Grande Railroad.

The ventilation of the mine, owing to the large size and roominess of the developments, is very good, and is increased by furnaces built at the ends of some of the entries.

The "face and end" or "butt" cleavage of the coal is very marked, and is a great assistance in breaking the coal down. The Lechner coal-cutting machines are used, worked by a Norwalk steam air compressor. The coal cutter cuts a horizontal distance of five feet at the base of the seam, each foot representing a ton of coal. After the undercutting, the coal is blasted down by powder and broken up by picks; one machine will cut 150 tons per day.

During the first seven years the production was about 300,000 tons per annum. In 1885 it was 96,592 tons of coke and 265,000 tons of coal. In 1888 it was 300,382 tons, since which time the production has largely increased. The cost of production was said to be about 73 cents per ton in 1885, and coal was sold at the pit mouth at \$1.00 per ton.

The coal is bituminous having a brilliant lustre, breaking in large, firm blocks, which slack but little from exposure.

This is one of the leading and older mines in Colorado, and from its dryness, roominess and perfect development, may be called an ideal coal mine. Perhaps the only deficiency is a lack of water which has to be brought in barrels from the Purgatoire river at El Moro, six miles distant, where a plant of two or three



hundred coke ovens is in active operation, the water being pumped up to them by steam power from the river.

THE TRINIDAD COAL AND COKE COMPANY'S MIMES AT STARKVILLE.

Leaving Trinidad we skirt the broad base of Fisher's Peak for about six miles along the south bank of the Purgatoire river, passing on the road several undeveloped exposures of two or three seams of coal. The scenery is picturesque. To the southwest the coal plateau stretches away to the Sangre de Cristo range, whose blue serrated outlines cut the horizon about thirty miles away. To the northwest the Spanish Peaks rise like gray pyramids above the plateau. To the east the coal plateau is seen to be abruptly cut off, and faces with its yellow wall the great plains, and on either bank of the stream the same plateau rises with its ashen-gray slope covered with piñons, the top capped with a characteristic belt of sandstone. A tributary of the Purgatoire, called Raton Creek, heads up to the south in the Raton pass, a gap which forms the gate-way through the Raton mountains to New Mexico, and is occupied by the track of the Santa Fe Railroad. We follow up this creek in the direction of Starkville. Along the road, within a mile of the village, we cross two small dykes of basalt, heading up towards Fisher's Peak, and passing directly through the coal-seams. These are some of the many dykes of lava which intersect this region, and which for the most part seem to have come up through one of the northwest and southeast cleavage cracks, which have cut up this entire region like a checker board. Their eruption appears to have little disturbed the adjacent strata, beyond baking it for a short distance, and sometimes producing a fine cleavage structure near the dykes. Most of these dykes besides emanating under Fisher's Peak, and being doubtless the immediate source of its lava cap, have a converging direction, pointing towards the Spanish peaks, thirty miles distant. These peaks are a center of eruption, and are formed by a concentration of an immense number of dykes issuing from one or more large laccolites as if the region had been violently fractured at this point, from which as a "focus," a multitude of minor fractures and fissures shattered the surrounding country, through which welled up the molten lava,

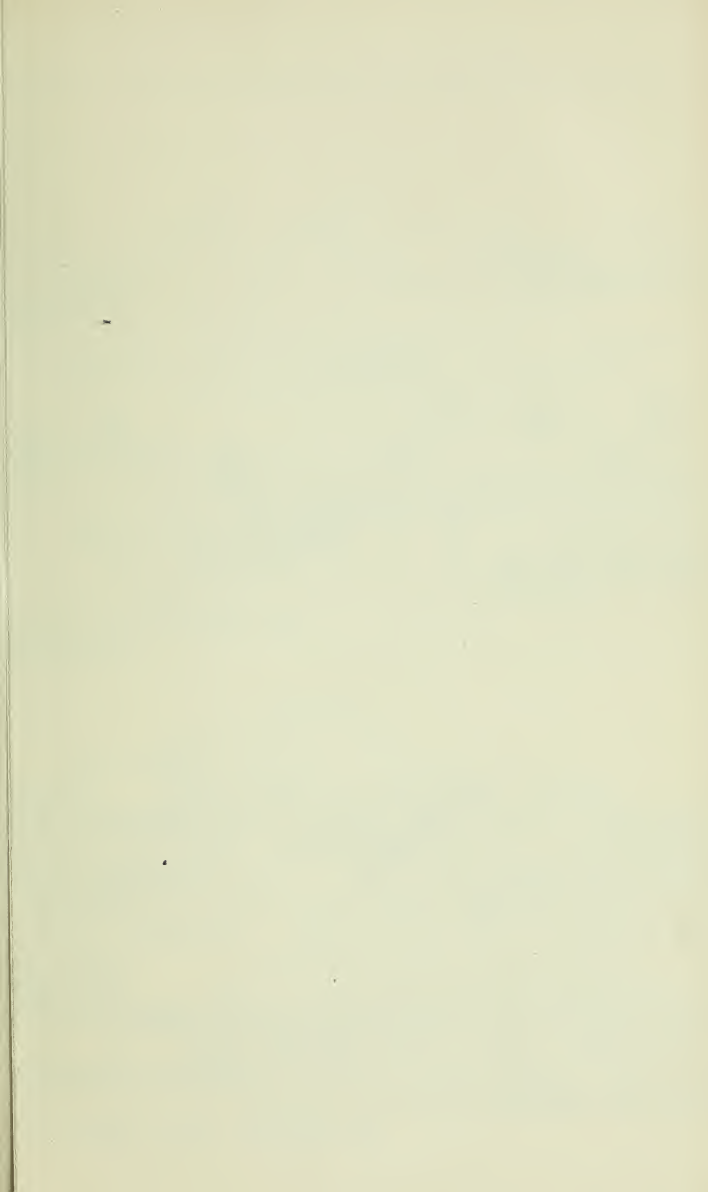


pouring a flood over the coal plateau, part of which still remains, capping Fisher's Peak, and portions of the Raton mountains, and preserving the coal strata in the position we find them. The heat from these dykes and overflows probably had the effect of partially debituminizing the surrounding coal, producing that coking quality which distinguishes it from other unaltered coals in the State. It is worthy of note that the districts in Colorado (Trinidad, Crested Butte and Glenwood), which produce the coking coals, are those where volcanic agencies have been specially active. At Trinidad local deposits of graphite are found, and a little south in New Mexico, anthracite, both in connection with dykes of lava, while at Crested Butte anthracite occurs, where the lava and eruptive agencies are most conspicuous. Anthracite and graphite are well known to be common coal metamorphosed by heat, and the coking condition appears to arise from the same cause more gently applied.

The little village of Starkville, numbering about 500 inhabitants, is situated on the banks of Raton Creek, in close proximity to the mine at the base of Fisher's Peak. The creek has exposed many natural sections of the coal strata and coal beds along its course. In one place the yellow massive sandstone forms the bed of the creek; upon this rests from 50 to 100 feet of shale, with a thin seam of coal two feet thick in the lower portion, and above it a thicker seam five to seven feet; the latter seam is the one worked. Higher up the creek, near Wooten's ranch, the same section and the same coal seam appears. Over the Raton pass, and on the south slope of Fisher's Peak, are the Raton mines, upon which considerable development has been done. These mines are also on the Santa Fe Railroad line.

The mines at Starkville are very similar in character and system of development to those at Engleville. The coal seam is not so thick, being six or seven feet, and so does not admit of leaving coal on the roof, hence the shale and sandstone require much more timbering for their support. The coal shows distinct lines of stratification and bedding, each layer of coal being about one foot thick; sometimes a little shale exists between the beds. The dip of the coal is to the southwest, rising three degrees to the east, with occasionally a rise or fall toward the north, caused locally by a few gentle "rolls."









DABALT CAP OF FISHER'S PEAK, RATON MTS.

Distant Sangre de Cristo Range.

ENGLEVILLE COAL MINES NEAR TRINIDAD COLO.  
COLORADO COAL & IRON CO.

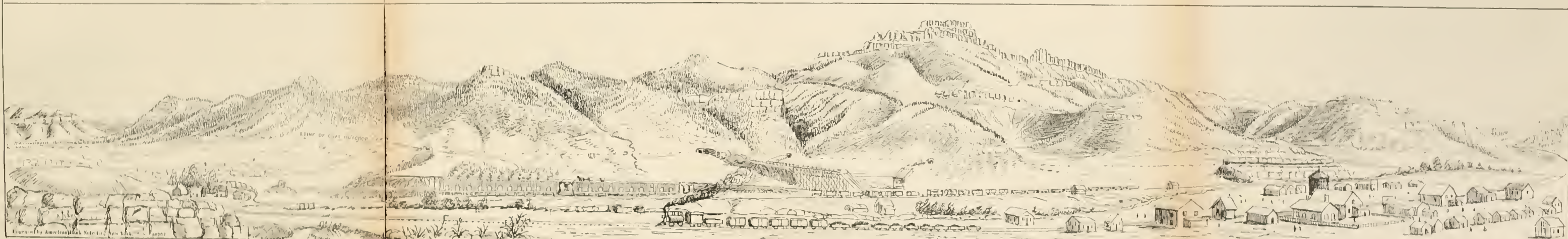
Spanish Peaks

A A COAL PLATEAU  
D TRINIDAD CITY

B B SANDSTONE BELOW COAL BEDS

C C MARINE CRETACEOUS SHALES BELOW COAL PLATEAU  
P Purgatoire River

Greenhorn Range  
El Moro town & Coke ovens



COAL PLATEAU

Prairie distant

COKE OVENS

STARKVILLE COAL MINES OF TRINIDAD, COAL & COKE CO.

Fisher's Peak

R Raton Creek

COAL EXPOSURE NATURAL SECTION

RATON PASS



The mine is practically level, the general outward dip to the outlets gives an excellent down grade for the laden cars. Some seams of fire-clay occur above the coal, said to make good lining brick for the ovens, also a belt of concretionary iron ore, which is found at several points around the mountain. The tendency of coal seams to break up into two or more seams by shale partings, and after awhile to come together again, is observable at this side of the mountain also. At both Engleville and Starkville, the lack of a copious supply of water situated conveniently to the mines is much felt, especially for the thirsty coke ovens. At Starkville this is remedied by bringing it in pipes from a spring five miles distant and high up on the mountains.

There are some eight principal entries, old and new, and the mine is developed on the same system as that at Engleville. The natural surface of the mountain being cut by little ravines, several cross entries to daylight have been driven, which contribute largely to ventilation. The coal is mined by pick and shovel, and by Harrison coal-cutters, worked by an air compressor with seventy horse-power engine.

A few rods from the mine is a long line of bee-hive coke ovens, built of sandstone and lined with Milwaukee fire-brick. The screenings are run direct from the shutes to the ovens along a tramway on top of the ovens. The rest of the coal is discharged from the top of a lofty trestle tramway connected with the main entries, into the cars of the Santa Fe Railroad. If the surface of the mountain of Fisher's Peak were removed, four little underground cities would be exposed, with their streets, alleys and blocks covering several square miles. This would give the stranger an idea of what has been worked out at Engleville, Starkville, Raton and Sopris, and the extent of these mines.

A general view of Starkville and its vicinity is given in Plate VIII.

#### SOPRIS MINE. (DENVER FUEL COMPANY.)

This mine is located four miles southwest of Trinidad, between the Purgatoire river and the base of Fisher's Peak, not far from the Starkville mines, its seams belonging to the same system, and its geology being similar to that already described.



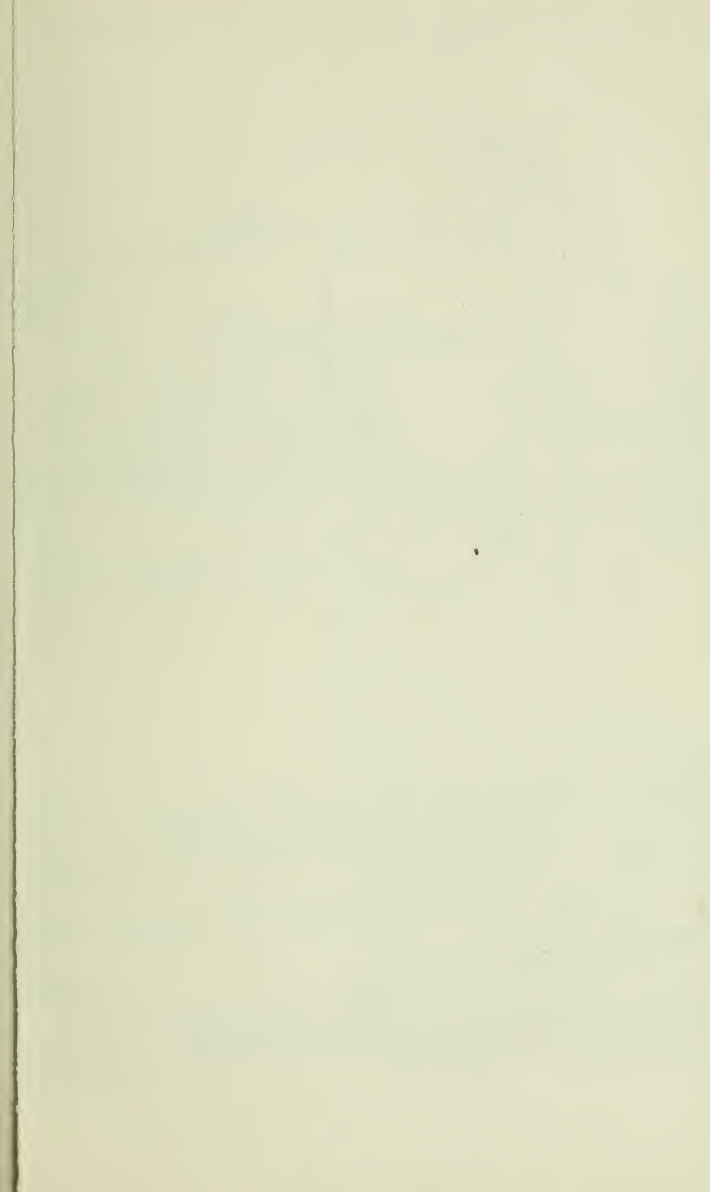
The openings are up a ravine in the mesa 1,800 feet from the track of the Fort Worth Railroad, and from the coke ovens and village of the company, located on the flat near the river. (See Plate VII.)

The coal is brought from the mines to the railway and coke ovens by a long wire-rope tramway, worked by a fifty horse-power engine. The dip of the strata inclosing the coal is about three degrees to the southwest. There are two coal seams, an upper one six and a-half feet thick, and a lower one forty feet below it, four feet thick; both of very pure coal, with little admixture of clay partings. The latter occasionally occur in an unusual position, filling joint cracks in the strata, at right angles to the bedding, and at intervals of from 50 to 200 feet. A few "rolls" also occur, as is usual in most mines.

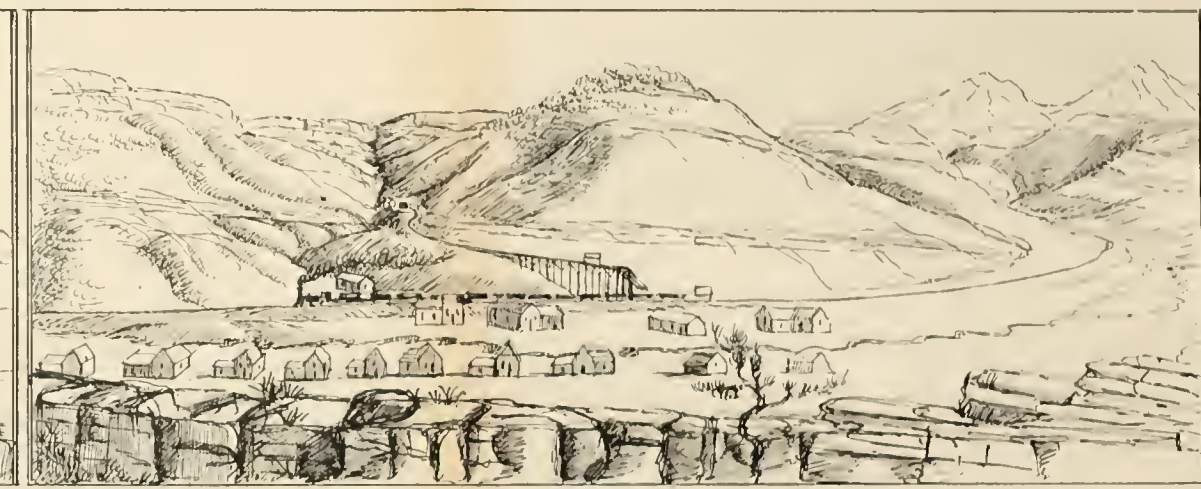
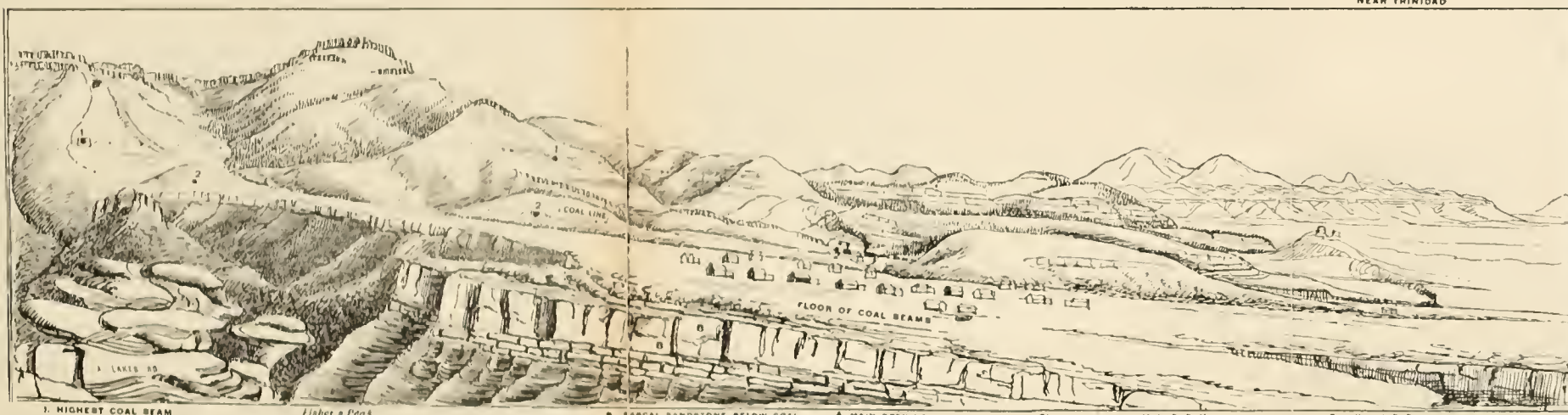
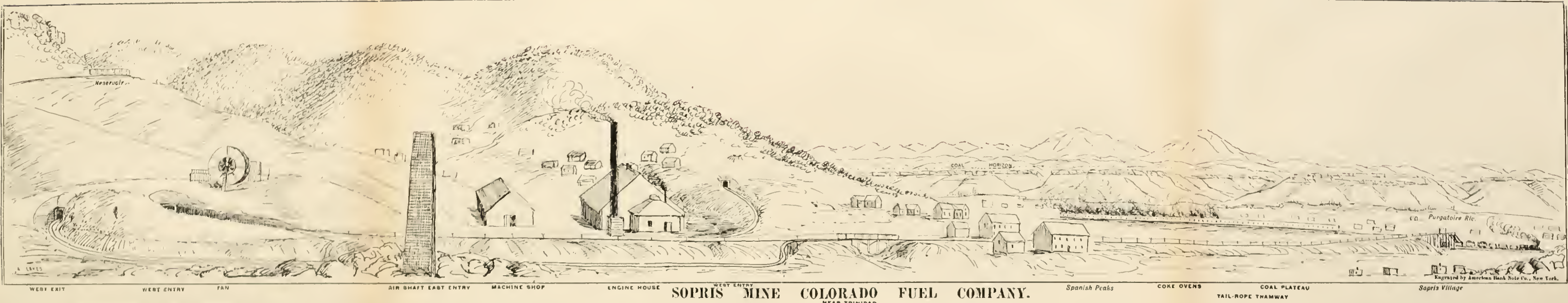
The main entry is 1,289 feet long, and from six to eight feet high; the coal is hauled to the entrance of the mine by mules, thence to the tippie by tramway. There are upwards of 14,957 feet of development in this mine, which is a large showing for the few months that it has been opened. Air is supplied by a fan and passes through the mine in a chamber running parallel with the main entry for 1,260 feet. The number of men employed is 450, of whom 350 are coal miners. The latter receive fifty cents per ton, the rest of the men being paid by the day. The daily output is about 1,200 tons. If "dead work," such as cross-cut through barren rock has to be done, it is paid by the job. Water for the mine is pumped up from the river about a mile distant, and stored in a reservoir above the mine. The coal is shoveled on to the railroad cars of the Fort Worth Railroad by the Ramsay steam coal distributor. All the most modern appliances of steam machinery are brought to bear, and the advantages of these improved time-saving methods are shown in the rapid development and large output of this young mine. Coal is shipped by the Fort Worth and Rio Grande Railroads, the markets being along their line, and also in Nebraska along the Burlington Route.

A plant of 100 coke ovens has been built at a cost of \$100,000. The return for coke from the ovens is about 66 per cent. or 175 tons daily. The ovens are circular, of the bee-hive pattern,











with a diameter of twelve feet. The coke is made from the slack and small coal. Twenty men are employed in connection with the ovens, and are paid at the rate of \$3.00 per day. Markets for the coke are at Omaha, and the Grant and other smelting works.

Analysis of the Sopris coal by Prof. George C. Tilden :

Water . . . . .	0.61	per cent.
Volatile matter . . . . .	33.18	"
Fixed carbon . . . . .	57.56	"
Ash (brownish gray) . . . . .	8.65	"
	<hr/>	
	100.00	"
Sulphur . . . . .	0.751	"

#### GRAY CREEK MINES.

See Plate VII.

These mines are located at the base of Fisher's Peak, about six miles east of Trinidad. The openings are along the small ravines tributary to Gray Creek, a little stream issuing from the Peak and flowing into the Purgatoire River. It has a good supply of water all the year.

#### TOPOGRAPHY.

The flanks of the Raton table land in this vicinity consist of rolling hills and benches divided by narrow but not very deep ravines, with here and there an intervening flat meadow. One of these meadows forming the bank of Gray Creek has been chosen for the coal village of Danforth, numbering some thirty new frame houses, and adapted from its proximity to water, for the location of coke ovens and other works in the future.

Up one of the ravines a side-track runs to the mines, and a locomotive transports the laden cars from the mouth of the mine to the main line of the Fort Worth Railroad at Beshoar station, about a mile distant. There the coal is dumped from a tipple direct into the cars.



## COAL SEAMS.

There are several seams on this property, some of them of workable size at a higher horizon than is common in this table land. The lower seams correspond to those worked at Engleville, Starkville and Sopris. There are also several localities on the property where the seams outcrop, and where in the future some of them could be conveniently worked.

Resting upon the massive "basal" sandstone is a seam about one foot in width, above this is a second seam and the one at present developed, from six to eight feet thick, which appears to be the continuation eastward of the main Engleville seam. About fifteen to twenty feet above this is a third seam of clean looking coal four feet thick.

Between 200 and 300 feet above these lower seams, is the upper series as shown on the section, Plate X, in which, on this property one seam attains six feet in thickness. In proximity to it is a bed of kidney iron ore of considerable thickness. Some of the lower seams at different localities are divided into several unworkable smaller seams by thick belts of shale. At one spot an intrusive sheet of basalt has entered the coal seam, and reduced it at contact to an impure graphite of about two feet in thickness. Dykes of basalt, doubtless once feeders to the main sheet of lava which caps the table land, are found here and there, and in one instance the development of a good coal seam would probably be cut off by one of these basaltic walls.

The seam at present worked, outcrops in plain view along the flank of the ravine, showing between six and eight feet of coal. Towards the center of this seam occurs a somewhat thick parting of shale about three feet six inches from the bottom, and varying from two feet to six inches in thickness, maintaining its course throughout the present workings. Near the bottom of the seam a thin parting of bone about one inch thick also occurs. These partings are an obstruction to the clean development of the coal and involve a good deal of extra labor. The miners have to cut 18 inches into the coal below the shale, remove the coal, then break down the shale parting, remove it separately, and lastly the upper two feet of coal is taken down leaving about



one foot of coal to support the roof. It is difficult to keep this shale and the seam of bone from mixing with the coal which would injure the coke by giving a high per cent. of ash. The coal is shipped and the small coal is sent direct to El Moro for coking.

The average dip of the coal seam is seven degrees and to the north. Towards the northwestern portion of the workings the dip increases to eight degrees, involving a steep up grade from the side entries and rooms towards the main entry, for the laden cars, which are drawn by mules. The cause of this steepness of dip is said to be the presence of a dyke of basalt about 500 feet to the northwest running parallel with the two main entries.

Several rolls occur in the mine, one large one in the main entry reduced the thickness of the coal considerably for a space, until it was cut through and the coal resumed its average size.

The mine is developed by two nearly parallel main entries which unite at the main outlet, from which side entries and rooms have been excavated.

The mine has been running about eight months and about 6,000 feet of development have been accomplished. The daily output has averaged about 350 tons. About 200 men have been employed. The work is by pick and shovel. Ventilation is at present by a furnace, but ere long a fan will be necessary. The Fort Worth and Rio Grande railways receive the coal and distribute it at various points along their routes.

The mine is owned by the Gray Creek Company, of which Mr. Delos Chappel is manager.

#### VICTOR MINE.

See plate VII.

This mine is located in the coal plateau sixteen miles north of Trinidad and four miles west of the Rio Grande railroad track. The works are situated about a mile up a ravine called the Cañon de Agua or water cañon, from the prevalence of springs near the head of the ravine. The next cañon to the south is the Chicosa,



up which runs a branch line from the Denver & Rio Grande main track to the Chicosa coal mines, worked by the Forbes Company. The side track from the Victor mine unites with this Chicosa line and both discharge their coal at Chicosa station on the main line. On approaching the great plateau from the open prairie we see before us an abrupt line of cliffs capped at the top by the basal sandstone, from which enormous fragments have tumbled down the slope. Above this floor at intervals, appear heavy masses from 100 to 300 feet thick, of shales and sandstones. In these are the coal beds.

As the strata of the plateau dip some four or five degrees to the southwest, the "basal" sandstone and its overlying coal beds are soon brought down to the level of the base of the ravine, bringing the coal within easy reach. The Victor mine is well located at such a point. The flat of the ravine affords an excellent site for the coal village, and the bluffs a good elevation for dumping coal into the railway cars, while the springs at the head of the cañon can be brought down by pipes to supply all the water necessary for the company's use. The main opening is up a side ravine and the coal is brought down from it to the tippie by a gently graded tramway. The main entry which is spacious and roomy, enters the side of the hill, and is eight feet high by ten feet wide, developing a coal seam six feet thick which has one seam of bone near the base. Coal was being mined at the time of our visit at forty cents a ton, the company supplying the blasting powder. A neat little coal village was in process of erection adjacent to the mine.

This property has but lately been opened, but when the works are complete a capacity of 500 tons daily is anticipated. There is another opening some distance up the gulch upon a coal seam ten feet thick, which either occurs at a higher geological horizon than the lower series or else attains its position by faulting. Time did not allow us to examine it. In the basal sandstone below the coal we found good specimens of the characteristic fossil *Halymenites* or *Fucoid* (seaweed).

This property belongs to the Victor Company, of which Mr. Delos Chappel is manager.



Analysis of the coal of the Victor mine, by Professor Regis Chauvenet:

Water . . . . .	1.26
Volatile matter . . . . .	36.40
Fixed carbon . . . . .	53.10
Ash (very light) . . . . .	9.24
	<hr/>
	100.00
Sulphur . . . . .	1.11

WALSENBURG DISTRICT.—ROUSE MINE, DENVER FUEL COMPANY.

This district is situated near the north end of the great Trinidad coal plateau. On the edge of this plateau and away from it to the east, down the Cuchara river, are low plateaus of shale and sandstone and as far as the eye can reach to the east, are scattered isolated mesas recording the once great eastern extension of the coal plateau. From the top of most of these mesas the coal has been eroded off, either exposing the basal sandstone of the coal, or else the softer marine Cretaceous shales of the Fox-hill group underlying the Laramie coal series.

The plateau in this neighborhood is riven at intervals by a series of eruptive dykes some of a porphyritic, others of a basaltic type, the former appear to be directly connected with a great line of eruption running north and south toward the western portion of the plateau and culminating in the Spanish peaks, La Veta, Sheep and Silver mountains. From all these peaks as from centers of eruption numerous porphyritic dykes radiate. The dykes of basalt which run out for miles on the plains may have been the result of a later eruption along the original line of volcanic activity. These dykes form conspicuous ridges or hog-backs at various intervals, some close together, some far apart.

Those appearing conspicuously above the surface of the present prairie were once surrounded by the plateau strata which have been eroded away, leaving the harder dykes standing out in bold relief. Others are met with traversing the cliffs of the plateau and running along the top of it. Others again are buried under drift and betray their presence by fragments of hard black rock lying on the surface. The mines at present opened, viz: the



Walsenberg, the Rouse and the Pictou mines, though several miles apart, have in their workings, all encountered one or more of these dykes or their offshoots, showing how much the strata must be interpenetrated by these volcanic phenomena.

Leaving the little town of Walsenburg which is situated on the banks and ancient bed of the Cuchara river, we drive for six miles in a southerly direction along the edge of the great plateau.

The prairie beneath our feet is composed of the marine Cretaceous shales, in which are occasionally found fossil sea shells. Above this for some 300 to 500 feet arise the abrupt cliffs of the plateau. In these a wide bay-like opening occurs, leading into the plateau by a shallow ravine. Here are the workings of the Rouse mine. (See Plate V.) A great semi-circular tramway, with a double tipple, raised on lofty trestles, spans the ravine, one tramway sloping gently from the coal openings on the north side of the ravine, the other correspondingly from those on the south side, uniting in the center at a double-tipple, by which the coal is discharged into the cars of the Rio Grande railway which has a side track six miles in length from the main line to this point. The village of the company lies inside this semi-circular rampart. The plant consists of two or three large engine houses connected with the workings.

There are two tail-rope engines which severally draw in and out the loaded and empty cars through the main entries of the principal openings by means of wire ropes passing over double cylinders and revolving in an endless rope system. Two Ramsey box-car loaders are also worked by steam. The engines are 125 horse power. Everything connected with these mines is conducted on the latest and most improved principles, a great deal of machinery and steam power being employed. The main drawback to the property is the lack of water in the immediate vicinity, all water for the use of the engines having to be brought by train for a distance of some miles. On the south side of the ravine near the trestle is one of the main openings, entering the gently sloping bank of the bluff at a slight incline of four degrees to the southwest, which is the average dip of the coal in this area. It follows down the coal from its outcrop on the surface. At some distance from the opening an air-shaft descends fifty



feet into the underground workings. Through the center of the shallow ravine, and of the property, runs the railroad track. On the opposite or north side, in a gently sloping park between the bluffs, are the two north-side main entries, with corresponding air shafts at intervals. The locality is a well chosen one for the coal workings, and a pretty situation for the neat little village of new frame houses nestling among the pinon trees. The gentle slope of the bluffs on either side give the necessary elevation and dip for the tramways leading from the mines. The railway runs the length of the property, at a level conveniently lower than the outlets of the mine. The coal can be worked on both sides of the ravine, tributary to one discharging point. The coal is easily accesible from the surface downwards, lying but fifty feet vertically below the deepest point, so that air shafts can be run to the surface without expense or difficulty, thus securing good ventilation, erosion having removed a great amount of rock from above the surface of the coal. The haulage on the gentle dip is easy and without strain on the machinery.

Our illustration will give an idea of the picturesque surroundings of the camp and the location of the works and mine. The plateau bluffs rising above the village are rounded, and about 100 feet in height, more or less covered with pinons and separated from one another by little ravines. Beyond the bluffs and the plateau, some twenty miles distant, rise the magnificent twin Spanish peaks and beyond them some thirty miles off are the long white crests of the Sangre de Cristo range. A little to the northwest and in line from the Spanish peaks are the La Veta and Silver mountains, all of the same volcanic origin. Still further to the north is the lofty terminus of the Greenhorn range whose summit is also capped with eruptive rock. The intervening country is a pinon-covered rolling one, part plateau and part uplifted hogbacks of sedimentary rocks. The latter occur mainly along the flanks of the volcanic peaks, and generally along the border of the Sangre de Cristo range. Here and there rising above the strata may be seen one of those wall-like dykes that intersect this remarkable region. For many miles to the west, southwest, and north, the monotonous coal plateau prevails. In the neighborhood of the peaks, lower Cretaceous rocks are



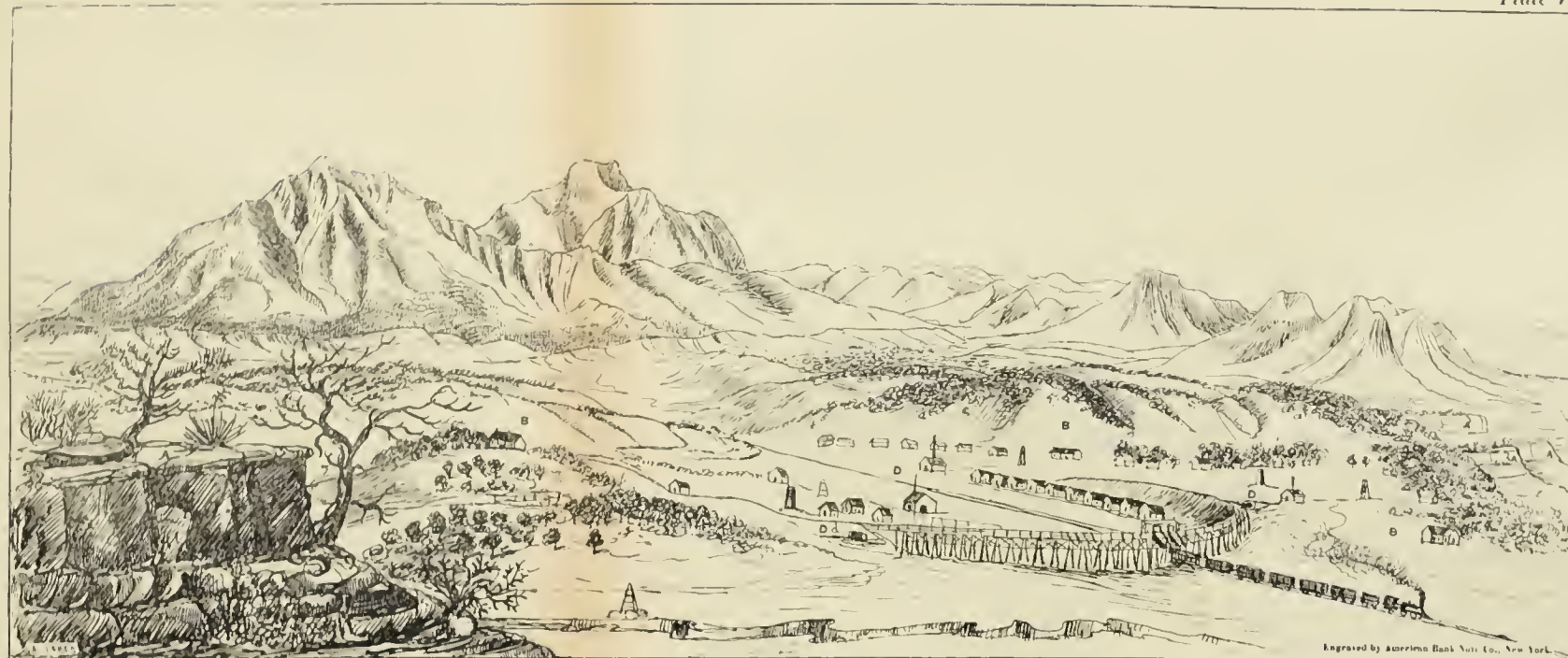
brought to light by uplift and erosion, and also, according to Mr. R. C. Hills, an enormous thickness of Tertiary rock gathers around the west Spanish peak. The Triassic and Carboniferous prevail west of the peaks and are uptilted against the Sangre de Cristo range of granite. The Laramie plateau to the east of this fringe of older strata forms a wide shallow synclinal basin or trough tipped up in the neighborhood of the Spanish peaks and dipping easterly, but some twenty miles east of the peaks, as for instance at Walsenburg and the Rouse mine and for some thirty miles or more down to Trinidad, the dip is in an opposite direction, viz; to the southwest, thus forming a shallow trough. To accomodate itself to the prevailing dip of the plains the plateau must again have formed an arch and again dipped east. This we believe is found to be the case some thirty miles east of the Rio Grande track. The top of the arch has, however, been eroded away for miles, leaving only a degraded outlie or mesa, here and there, to mark its former existence. If we reconstruct therefore the ancient coal plateau in its entirety, we should have two folds, one a synclinal trough to the west, an another an anticlinal arch to the east.

About half a mile to the east of the Rouse mine the "basal sandstone" caps the top of the bluff from which the accompanying sketch was made. The coal had been removed from it by erosion. The southwest dip of this bluff shows that its sandstone cap would eventually pass under the coal found in the Rouse workings. As the dip is four degrees to the southwest, the entries in following the coal have to be driven down in that direction, consequently, traction engines drawing laden cars up a gentle incline, are a necessity in the mines of this district, while in some others, as at Trinidad where the dip is downward toward the outlet of the mine, only gravitation is required. The traction wire ropes on this south side pass down through a bore hole near the end of the main entry for fifty feet, then along the line of the track through the entire length of the entry over a series of rollers, and then over a number of trestles on the surface, the wire being connected with a stationary engine, thus the traction power of the rope works in an endless ellipse.









Engraved by American Bank Note Co., New York.

A BANDSTONE BELOW COAL BEDD. *Spanish Peaks*  
 D COAL OPENINGS  
 ROUSE COAL MINE.  
 DENVER FUEL CO.  
*Sangre de Cristo Range*  
 La Veta Peak  
 Dyke Mt.  
 B STRATA COAL BEARING, OF COAL PLATEAU



The coal will be found inexhaustible as the workings are pursued under the plateau.

The slope on the south side descends by a grade of four degrees in a direction south  $20^{\circ}$  west; the tunnel is wide and roomy, about eight feet in height, developing a six foot coal seam, it is wide enough to accomodate three separate tracks, two of which are at present in use. Heavy timber is used to support the roof, which is shaly and poor. At some distance within the entry a dyke of basalt is encountered as a formidable obstacle, for the workings have had to meet it diagonally instead of at right angles, and though its thickness is not more than thirty feet, this cutting at an angle involves a much greater distance. The dyke is of adamantine hardness, using up the drills very quickly, but blasting well. For thirty feet on either side of this dyke the coal has been changed to a kind of hard, natural coke, with its cleavage planes at right angles to the sides of the dyke. Fragments of coal over a yard in diameter have also been caught in the molten embrace of the lava dyke and similarly changed to coke. Little seams of iron pyrites are found near the dyke. In some places, either by calcination or the access of water through cracks, the basalt is reduced to a soft kaolinic condition. The usual "butt and face" cleavage of the coal as it nears the dyke is deflected into a slanting direction. Owing to the strike of the dyke, and the necessitated following of a southeast direction in developing the mine, rooms and entries for a while are liable to come across this same obstruction. The coal immediately adjacent to the coke does not seem to be affected, further than that it is of unusually good quality, the transition from coal to coke seems quite abrupt. No bone or shale partings are observable in the coal seam, but near the lower portion, a thin seam of half an inch of soft clay occurs continuously, but is not detrimental to the coal, which may be considered as absolutely free from foreign impurities and maintains its thickness and character throughout the mine with great uniformity.

The coal breaks in large hard blocks of a bright and anthracitic lustre, is not affected by wheathering, and is said to stock well in the coal yards.



The workings on the opposite side of the ravine are similar to those we have described, with the exception that they are not troubled with dykes, but have met with a fault which dropped the coal seam twenty-five feet.

The length of the main entry on the south side is 1,000 feet, with rooms and side entries branching off from it. The length of the main west entry on the north side is 800 feet. There are in all about 7,500 feet of entries and cross entries, and about 150 rooms now working. The coal seam is six feet thick, with shale roof and sandstone floor. These mines are not over a year old, but have accomplished a large amount of development in that time. In favorable seasons, the daily output is 1,300 tons. The principal markets are along the Burlington road to Nebraska and Kansas, also to Pueblo and Denver. There are two tail-rope engines, one on the north the other on the south side; the rope on the north side is 900 feet long, that on the south, 1,500. The tail-rope engines are 125 horse power. The double-dump trestle is 250 feet long and fifty feet high. Ventilation in the mines is at present good, and is assisted by open furnaces and by air shafts; fans will be erected when needed. There is no gas in the mine, and the workings are exceedingly dry. The coal is said to cake but not to coke, leaving no clinkers in the fire, but only a white ash. Above the main seam is a small two foot seam of coal which the lava has entered, and spread out in it as an intrusive sheet along the line of least resistance. About 500 men are employed. The coal is mined by pick and shovel at sixty cents per ton. The mines belong to the Denver Fuel Company.

Analysis of the Rouse coal from the south side entry, by Professor Tilden :

Water . . . . .	2.66
Volatile matter . . . . .	36.71
Fixed carbon . . . . .	51.41
Ash (light brown) . . . . .	9.22
	<hr/>
	100.00
Sulphur . . . . .	1.373



PICTOU MINES, (SOUTHERN COLORADO COAL CO.)  
AT SULPHUR SPRINGS.

Returning to Walsenburg we examined the bluffs on the south side of the Cuchara river. These belong to the Fox-hill group of the Cretaceous, and consist of a great thickness of drab shales underlying the coal sandstones. About 100 feet below the top of the bluffs is a stratum of calcareous concretions of elliptical shape much flattened by compression. They are very hard, but owing to their septarian divisions readily break up into small blocks. We could find no fossils in them. These concretions have been thought of as an element for making Roman cement. They are often so close together as to form a consecutive stratum about two feet thick.

From Walsenburg we crossed the valley of the Cuchara in a northwest direction towards a lofty abrupt ridge which we found to be caused by a formidable dyke of basalt, running northwest and southeast coming up through the coal sandstone. From the top of this we descended into a narrow valley about a half a mile in width, bounded on the northwest by a similar and parallel dyke, but not of such formidable thickness. Through the center of this valley flows a stream of tepid water highly charged with sulphuretted hydrogen, which issues from a powerful spring from the underlying coal beds between the two dykes, its chemical elements being doubtless derived from the coal seams.

The workings of the Pictou mine with its accompanying trestle tramway and tipples discharges coal into the cars of a branch line of the Denver & Rio Grande railroad, (connecting with the main line at Cuchara station some six miles distant), and occupies the center of the valley. Around the workings is the village of the coal miners. The several openings enter the base of the bluffs on three seams of coal which outcrop on the surface. The dip of these seams is seven degrees and in a southwest direction.

The upper Lenox seam is five feet six inches thick. Thirty-five feet below this is one between two and three feet thick. Fifteen feet below this again is the Maitland seam four feet thick.



Entering the Maitland incline we find a good deal of water dripping from the roof. This water by its sulphuretted character has a bad influence upon the iron of the boilers and machinery, by corroding it at the joints. As these workings are leading down in the direction of the source of the sulphur springs, pumps will become a necessity. The workings, as usual in narrow seams, are cramped. Cross entries and rooms were in process of excavation. The main entry has so far reached a distance of 450 feet. The seam is free from partings of bone or shale; there is a half inch seam of clay similar to that of the Rouse, to which coal seam, except in thickness, this one is supposed to correspond. The two foot seam cut by the main entry slope is not of sufficient size to work. The roof of these seams is of shale, and poor.

Above this we enter the slope on the upper or Lenox seam, the main entry slope owing to the greater size of the seam is high, wide and commodious, but owing to a poor roof it requires careful timbering. In the upper part of this seam, which is five feet six inches thick, there is a shale parting about one foot thick which cuts off one foot of coal from the workable thickness. This parting, together with the overlying foot of coal, is left to strengthen the roof. The peculiar structure of this coal consists of a series of hard spherical concretions from the size of an egg to a foot or more in diameter. These concretions are of hard coal with an anthracitic polish on the outside.

The coal area is limited on the north and south by the parallel dykes, but not so toward the west. There are other workings in this area, and in one of them on the Maitland seam on the north side, three small dykes are encountered, each about eighteen inches thick and about fifty feet apart. They appear to be offshoots from the main dykes and are not met with near the surface. They have had no influence on the coal. This mine has been only a year in operation; its output is about 400 tons daily. Forty miners are employed. A good deal of this coal is shipped to Kansas. The company is the Southern Colorado Company, of which J. K. Robinson is manager.

Analyses of the coal of the Pictou mines, by Professor Regis Chauvenet of the School of Mines:



## LENOX COAL SEAM.

Water . . . . .	2.92
Volatile matter . . . . .	41.18
Fixed Carbon . . . . .	45.36
Ash (very light) . . . . .	10.54
	<hr/>
	100.00
Sulphur . . . . .	1.39

## MAITLAND SEAM.

Water . . . . .	3.10
Volatile matter . . . . .	38.12
Fixed Carbon . . . . .	48.58
Ash . . . . .	10.20
	<hr/>
	100.00
Sulphur . . . . .	2.04

## NORTH WESTERN END OF THE COAL PLATEAU.

Beyond the Pictou mines and the property of the Southern Colorado Coal Company, the Coal Plateau extends some seven or eight miles further to the northwest, when it is abruptly terminated by the erosion of the valley of the Huerfano River. A little ravine known as the "Coal and Carbon Arroya" at the base of the plateau forms part of the natural northwestern boundary line of the coal field. Beyond this to the north the broad valley, through the centre of which the Huerfano River flows is underlaid by Fox Hill Cretaceous shales, which are not coal-bearing. We found some Baculites and other marine shells thrown out of prospect holes which had been dug in a vain search for coal. Wherever, in Colorado, these shales are found underlying a tract of country, it is useless to prospect for coal there. The shales will generally show some fossil shells, and the discovery of these may be considered a rough guide for identifying these particular shales, as fossil shells are rarely found in Colorado in any other set of strata. In this region the piñon trees are also a useful guide, for they generally grow on the coal bearing strata, but rarely on the non-coal-bearing shales.



North of the river is the terminus of the Greenhorn or Wet Mountain range formed of Archean rocks, and from the north, along the western boundary of the plateau, stretches a line of eruptive hills of "Laccolitic" structure. The most northerly of this group is Badito or Sugar-loaf peak, a laccolite, whose bald head of grey volcanic rock peeps up above a ring of mesozoic strata tipped up on all sides around it. In a line with this are smaller hills of dark, eruptive rock, called the Black Buttes, and a star-shaped laccolitic called Silver Mountain, from which radiates a great number of dykes. Behind these, a little to the west are two or three straight topped, steep looking hills, called the Sheep and Veta Mountains; all of eruptive origin, and of laccolitic structure composed of porphyritic rock. These laccolites according to Mr. Hills, are thick sheets of lava, intruded horizontally among the Colorado Cretaceous shales, and resting upon them as a base. The strata lying above these thick intrusions were cracked by them, and lava welling up through the cracks filled them with dykes. One or more main dykes also came up from depths unknown, as feeders to the main intrusive laccolites. These eruptions, according to Hills, occurred towards the middle of the Tertiary period, and were incident to upward movements in the Sangre de Cristo and Wet Mountain ranges; movements which have also produced the foldings we find in the coal plateau.

This line of eruptive hills forms the approximate western boundary of the coal fields in this section. On the east the coal plateau is limited as farther south by the erosion of the great plains. This northern section of the plateau preserves the same uniform characteristics we have found throughout it as far as Trinidad. It is tipped up along the eastern edge to about 10 degrees, dipping southwest, forming part of that broad, anticlinal arch we have mentioned before, whose continuity eastward has been largely removed by the erosion of the plains. To the north also, it shows the influence of the Greenhorn uplift, and dips south, while to the southwest it is uptilted even to verticality by the movements of the Sangre de Cristo range; thus forming a long, shallow trough between its eastern and western margins. A large area around and west of the laccolitic hills, extending from the Huerfano River on the north to the Spanish peaks in the south, has







Adapted from Hayden's Survey



Plate VI.





been shown by Mr. Hills to be covered by a great thickness of Tertiary beds lying unconformably on both the upturned Laramie and Colorado shales. It occupies an extensive basin, formed by the folding of these latter groups. The Tertiary character of these deposits has been further proved by the discovery of fossil turtles and mammalian bones of Tertiary type.

All along the eastern and northern edge of the plateau the yellow massive basal sandstone rich in impressions of fossil *Halymentites* is seen outcropping and immediately underlying the lower coal seams, and overlying the non-coal-bearing Cretaceous shales. The plateau is traversed here and there by a parallel system of dykes of basaltic character having a general northeast and southwest course. One of these dykes we pass near the boundary line between the Southern Colorado and Pinon Company's properties and another at the northeastern corner of the plateau. The columns of the dyke resulting from cleavage fractures at right angles to the cooling walls lie horizontally like so many logs of wood piled one on top of the other. The same phenomena may be observed in a dyke crossing the plains a few miles north of El Moro. The isolated "Huerfano" or "Orphan butte" is also the relic of a dyke, standing prominently by itself in the Huerfano valley.

Outcrops of coal are shown by prospect holes all along the eastern margin of the Pinon Company's property at the usual horizon above the basal sandstone and occurring at intervals up through the four or five hundred feet of sandstones forming the top of the plateau. According to Professor Benjamin Sadtler, who examined and located this property for the Pinon Company, there are as many as five different seams at intervals above one another in these sandstones. These are in ascending order:

- 1.—9 feet thick with two partings and resting on the basal sandstone.
- 2.—4 feet 6 inches fifty feet above the last.
- 3.—3 feet 8 inches seventy-five feet above No. 2.
- 4.—3 feet 3 inches forty feet above No. 3.
- 5.—5 feet two hundred feet above No. 4 and near the top of the plateau.



The large tract adjoining this property on the northwest together with that of the Pinon Company, was by some error not included in the coal plateau or marked as coal land in Hayden's economic map. According to that map the plateau and coal series terminate very near the Pictou mines, whereas both the coal and plateau extend some seven or eight miles to the northwest beyond this point. A singular oversight, considering that not only does the Halymenites sandstone, the well recognised floor of the coal, outcrop all around the tracts in question, but coal itself in several seams as we have shown, and at various places comes plainly to the surface. Along the Carbon arroya these brown weathered outcrops of coal have been developed at several points showing one seam in particular, and that the lowest, to be 6 feet thick of very pure coal, with scarcely a trace of bone or other parting. The sandstones too, throughout the hill above are full of fossil leaves, such as *Platanus*, fronds of *Palmetto's*, and traces of carbonized vegetation, proving the Laramie coal-bearing character of the entire hill of strata.

The land is unquestionably coal land of a valuable and available character, and from the practical impossibility of irrigating it, let alone the shallowness and rocky character of the soil, it is as valueless for agricultural purposes as it is valuable for coal. The same applies to a large marginal area outside of the land in question which is as certainly coal land and should so have been represented on the economic map of the Hayden Geological Survey. We have endeavored to make an approximate correction of this map in plate VI.



## CHAPTER VIII.

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### The Durango Coal Region.







## Chapter VII.

### THE DURANGO COAL REGION.\*

#### SOUTHWESTERN COLORADO.

From the Trinidad region we set out to examine the coal fields of southwestern Colorado whose developments at present are confined to the neighborhood of the city of Durango. Our course led us across the Sangre de Cristo range by the La Veta pass, thence through the San Luis Park and over the Conejos range into the plateau country of southwestern Colorado, principally occupied by the Ute reservation; thence up the Animas river to Durango, which is not far from the La Plata and San Juan mountains. As this route and country is not so generally well known as some other parts of Colorado, we shall describe its geological features in some detail. Our first halt was at the village of La Veta from which we have a near view of the Spanish peaks. From the main masses of the peaks we see long dykes like artificial walls of masonry radiating in various directions. The eastern peak is composed of one solid mass of lava and is united to the western peak by a saddle of the same material. A large portion of the latter mountain appears to be composed of nearly horizontal sedimentary strata, riddled and cemented together by dykes and volcanic matter. These have by their heat metamorphosed the strata, which, according to Mr. R. C. Hills, belong to the Tertiary. As we ascend the La Veta pass we are not far from Dyke or Silver mountain, which, as its name implies, consists of a series of dykes radiating from a common center. Further on, the train winds around the foot of La Veta mountain. This appears to be a Laccolite, for the red sandstones tip up all around the massive central cone of lava at an angle of forty-five degrees. The cone is composed of a thick mass of white porphyry, from which also many dykes emanate. As we climb the Sangre de Cristo range, coarse, red sandstones appear dipping

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\* See Frontispiece.



east, these, according to Endlich, are Carboniferous, though a good deal of that marked on the map as Carboniferous has been shown by Mr. Hills to be Tertiary. Several dykes appear issuing from the granite. Over the pass we find limestone, probably Lower Carboniferous, reclining on the granite. The Sangre de Cristo range seems to be an anticlinal arch of granite, once overlaid by Carboniferous strata, remnants of which are still left.

#### SAN LUIS PARK.

We descend gradually into the wide prairie-like basin of the San Luis Park and look back on the range we have passed. The most striking object is the Sierra Blanca, the highest peak in the Rocky Mountains, a huge mountain mass standing somewhat by itself. The top of the mountain is excavated by glacial agency into a deep amphitheater not unlike a volcanic crater, from which radiates a series of cañons down which the glaciers once moved from their source above.

From Blanca as a center the snow-capped Sangre de Cristo peaks form the eastern boundry of the park. To the south a belt of volcanic cones, dykes and lava-capped table-mountains circle around and unite with a great lava overflow constituting the Conejos and San Juan ranges, which form the park's western boundry. This volcanic belt suggests the formation of a series of cracks around the rim of the basin, coincident with the time of its folding up by the movements of the surrounding mountains. From these, eruptions, mostly of basaltic lava, poured down into the basin and assisted in forming its floor. At one period the entire park was filled with a great sheet of fresh water which has left behind it lake-beds of considerable thickness, so if the coal stata existed at all in this area they are covered by these later formations. Artesian wells have been sunk with good success at various points and have brought up water from moderate depth. At La Jara, a well bored only 80 feet throws up a large volume of water with considerable force in the open street of the town.

At Antonito the railway station is built of a black vesicular basalt whose cavities are filled with white zeolites. This stone is derived from lava flows which emanated from a cone surmounting



a sloping plateau of lava about six miles northwest of the town. These flows grade off into the basin of the park at a dip of five to eight degrees. This hill is suggestive of a true volcanic crater, and according to reports, a cup shaped cavity occurs at the summit. This crater together with a line of dykes and volcanic outbursts forms a preliminary fringe to the Conejos range which we presently enter through a series of table-lands and terraces of lava with occasional patches here and there of stratified "tuff" and further on heavy masses of volcanic "breccia" eroded into monuments, "hoodoos," and other curious forms which have given the name to the cañon of "Toltec" gorge. The thickness of this lava is at least 2,000 feet as we see it shown in sections in the gorge, at the narrowest point of which a spur of granite appears, upon which the lava rests directly, and from this point for some miles granite continues with only a slight covering of lava. Thus this range appears to have been a granite uplift flooded by lava. The blocks of lava in the "breccia" are some times three feet in diameter and several hundred pounds in weight.

#### UTE RESERVATION IN SOUTHWESTERN COLORADO.

On emerging from this range we descend into the well timbered valley of the Chama river and look down upon the region of southwestern Colorado, characterized by table-lands, consisting principally of the Laramie coal series underlaid by the Fox-hills Cretaceous shales, traversed here and there by eruptive dykes which have sent outflows of lava over some of the plateaus. Thus it is a repetition, only on a much grander scale, of what we have described in the Trinidad region.

The plateaus with their attendant coal seams extend over hundreds of square miles, cut up at intervals by cañons and river courses into tables and castles, and tilled up and interrupted towards the northwest by the volcanic La Plata and San Juan mountains. It is scarcely an exaggeration to say that before us as far as the eye could reach, lay one vast coal field extending beyond the limits of Colorado into Utah and Arizona.

So far as we could judge from the train, this plateau tips up slightly against the Conejos range, and emerges from under its



lava cap. In the valley we soon observe the yellow "basal sandstone" capping a table land of shale 600 feet in height, consisting of the Fox-hills group, out of which the valley of the Chama has been hollowed, and to which it owes its fertility. The western dip (three degrees) of the strata gradually brings them together with the overlying coal beds to the level of the valley, a descent hastened near Monero by faulting. Here the coal is mined by the Rio Grande close to the railway track. Some fine looking yellow sandstone is being quarried near the mines.

For miles we follow the monotonous plateaus to Amargo where a valley about five miles wide has been hollowed out of the group. A little beyond the station some remarkable dykes of basalt cross the valley in an east and west direction, and can be easily followed for a long distance by their wall-like outlines and dark color as they ascend the cliffs of sandstone and enter the plateaus, maintaining a parallelism as exact as though laid off by a compass. Four of these little parallel dykes from three to four feet wide and a few feet apart are passed close to the track at Navajo station, and further on a dozen of them may be seen running in parallel groups through the natural cleavage joints of the sandstone, which they doubtless enlarged and filled.

Not all of these castles and table lands carry coal, for at some places, as at Caracas station, the coal has been shorn from the top of them, only however, to be resumed again at Arboles. From Arboles to La Boca station the coal appears to be overlaid by some 600 feet of Tertiary beds, consisting of variegated pink, maroon, and greenish shales and sandstone, forming table lands, in which but little coal may be expected.

In our course through this well watered country we cross several streams tributary to the San Juan river, such as the Pedro, Piney, Navajo, etc., and for some distance keep along the banks of the San Juan itself, a fine stream from 50 to 100 yards wide, having considerable fall. Between La Boca station and Ignacio, detached mesas and outliers of the series occur, but the prevailing rock is the Fox-hill shale, which continues till we near Durango. As we approach this town, many square miles to the south are occupied by low mesas of reddish brown Tertiary strata, the coal plateaus swinging off more to the north along the flanks of the



La Plata and San Juan mountains. This region at present belongs to the Utes, and is characterized by low table lands often well timbered and intersected by numerous streams and water courses. The fall of these streams is such, that ditches from them could easily be carried over the mesas, and irrigate large tracts of country now unutilized. It is a well-watered "promised land" of the future. The Durango people are impatiently awaiting the time when the Utes shall go, and they shall enter in and possess this good land with its coal, grazing and farm lands. They are also looking eagerly for a railroad line into New Mexico or Arizona, as a southern outlet and market for their coke and other products. As we ascend the Animas river, the hitherto flat strata of the mesas begin to bend upwards at an angle of 15 to 30 degrees, caused by the uplift of the La Plata and San Juan mountains, whose snowy peaks appear to the northwest, and around whose flanks a great thickness of strata from the Silurian to the Tertiary is lifted up, and among them the Laramie coal beds, and their underlying Fox-hill shales.

#### GEOLOGY OF THE DURANGO DISTRICT.

The first in order as we ascend the river is the Tertiary, forming the flank of a Laramie hogback, whose thickness is upwards of 1,000 feet; a reference to the colored illustration will show this relation. A good place to bore for artesian water, gas, or oil, would be somewhere near the point below which the Tertiary strata bend down from the back of the ridge and pass under the flat mesas of the Ute reservation, one side of a basin being thus formed. The great Carbonero coal seam, of which we shall speak hereafter, would be tapped by such a bore at a depth not exceeding 2,000 feet. As this seam carries an extraordinary amount of gas in it when it lies below water level, it is not unreasonable to suppose that this gas might be tapped at the point we suggest, some six or eight miles from the town of Durango. The train now carries us along the course of the Animas, past this mass of uplifted strata. The Tertiary beds consists of thick, reddish, rusty conglomerate resting upon shales and heavy-bedded sandstones of the Laramie group. The first hogback or block of strata ends abruptly in a cliff about 1,000



feet high, composed of Fox-hill shales capped by the basal sandstone and overlying coal beds.

In this mass of strata there are two separate belts of coal, the lower overlying the basal sandstone and containing a half a dozen small seams from one to five feet in thickness. These are developed in another part of the field by the San Juan, Shores, Porter, Black Diamond and City Bank mines, most of whose workings are in seams of very good coal, rarely exceeding four feet in thickness.

A hundred or more feet above these is the upper belt of coal seams of enormous thickness known as the Carbonero, from the prominent mine of that name. This belt has been traced for a great distance; it consists of an aggregate of many coal seams of varying thickness. These are sometimes so close together that they constitute almost a solid body of coal, split up, however, by numerous shale partings; at other times the different component seams stand well apart and can be worked separately. This belt has been traced from Durango to Florida and beyond a distance of 70 miles, and might doubtless be followed much further. It is this belt, no doubt, to which Professor Newberry refers when he says: "On the San Juan and its tributaries is quite an extensive coal field, and I have ridden many miles along the north side of this river where its banks contain a continuous coal seam from 30 to 50 feet in thickness. This is, however, like all such great seams, far from homogeneous, layers of good coal 2 or 3 feet in thickness, alternating with layers of slaty coal; but near the mouth of the Animas I noticed another seam 6 feet in thickness, which was fairly uniform in composition." Near Durango these seams will aggregate 80 to 90 feet of coal, of which a good deal is workable. The belt appears to run along the Atlantic Divide, extending down to Gallup in Arizona. It swings around the La Plata and San Juan mountains where it is uplifted by those ranges, and again becomes horizontal in the Montezuma valley. Apart from the distinct outcrops of the coal itself in the various ravines, it can be followed even from a long distance by the eye, by a sharply defined valley which it makes in the hogback, often 100 or 200 feet deep; the soft coal having yielded to erosion more easily than the confining sandstones. In the neighborhood of



Durango there are but three mines in this belt—the Carbonero, on the east bank of the Animas close to the Rio Grande track and the bed of the river, another some five miles east of it called the La Plata, and a third in the hogback west of the river called the California. Only the La Plata is at present working, the market for coal being confined to the city of Durango and some of the mining towns, for which four or five mines nearer the city are competitors. But a time will come when the Ute reservation being thrown open, an increased population and greater railroad facilities will cause many new prospects to be developed upon this phenomenal coal belt of Colorado.

Proceeding up the river we are apprised of the reason of the steep ending up of the hogback by the appearance of a second very similar ridge rising from the base of the last. The shales are likewise capped by the same basal sandstone upon which remains, however, but 100 or more feet of coal bearing strata. Such a duplication of strata within an interval of a mile or so, suggests a fault, and that the lower bench was once a continuous part of the tipper one, from which it has broken off and fallen down, while the other remained constant or was in turn uplifted. As also we only find the lower series of smaller coal seams in this second hogback, we conclude that after it fell down, the upper or Carbonero belt was eroded off from it, leaving only the lower seams. This is confirmed by finding at the La Plata mine, where the strata are entire, seams that correspond with those of the Porter and San Juan mines, overlaid by the whole of the thicker group. Our illustration, which was taken from above this mine will make this clear and also show the nature of the fault. The two series in the twin hogbacks, originally but 100 feet apart, are now separated by a valley a mile or more wide of faulted ground in which the Shores mine is working on a four foot seam, and by a thickness of 1,000 feet of shales. The greater Carbonero series is seen swinging away towards the west in the direction of the Montezuma valley, while the lower series keeps on towards the La Plata and San Juan mountains. Numerous ravines cutting through the soft Fox-hill clays dissect these hogbacks, leaving here and there prominent castle-rocks as shown in the picture, close to the town. The city



of Durango, with its handsome villas, fine hotel, and smelting works, is located in the valley of the Animas upon the lower portion of these Fox-hill shales, covered by a considerable thickness of glacial drift. North of the town we follow the Animas river up into its beautiful cañon, and in ascending, pass, geologically, down through the whole strata of the earth's crust, period following period of uplifted strata, down to the granite "bedrock." First, underneath the Fox-hill shales, outcrops the hard white sandstone of the Dakota Cretaceous. The later cannot deeply underlie the streets of the city, and from it probably the projected artesian well, when bored, will derive its water, contained in the joints of the sandstone, well confined by overlying shales. The dip of these strata is to the south. Next in order and beneath this are a few hundred feet of variegated shales belonging to the Jurassic. Then a massive cream colored sandstone appears, capping the Triassic rocks, which consist of a great thickness of red conglomerate sandstone. Beneath these again at Tremble Springs we see the purplish sandstones of the upper Carboniferous, and below them the Lower Carboniferous and Silurian limestones and finally the Cambrian quartzite resting upon "bedrock" granite near Rockwood.

As we approach the Needles and the town of Silverton, we find enormous volcanic overflows covering all strata alike and overwhelming them for hundreds of square miles beneath a thickness of from 2,000 to 5,000 feet of lava constituting the San Juan mountains.

This completes the geological features of this district, which will be better understood by reference to the colored engraving and its accompanying sections. The scene depicted in the sketch shows the peculiar plateau characteristics of this region and was selected by the writer as one of the most striking illustrations of a great coal field to be met with in Colorado or elsewhere, a field of inexhaustible resources awaiting the removal of the Ute, the advance of civilization, and the opening up of more extensive markets.

#### THE PORTER COAL MINES.

A small creek, called Lightner creek, comes into the Animas from the west, about half a mile from the city. It cuts through



the shales and lower sandstones of the coal series, and, as we ascend the creek, the western dip, at about four miles from its mouth, brings the coal sandstones down to the creek level, and here the Porter mines are located, with several openings on different seams. The first opening is a tunnel, 1,800 feet long, passing clear through the hill and coming out on the other side in a little ravine, on the opposite side of which the tunnel is being continued for a few feet on the outcrop of the seam. A bridge thrown across this ravine can connect with the main tunnel, and carry the coal on a downward dip to the general discharging point. The seam developed is 3 feet 6 inches, of very good pure coal, unalloyed by bone or shale. The mine is developed on the Long-wall system, and rooms thirty feet square are run off from the main entry. Some difficulty was experienced in the early days of the development by a heavy roll encountered near the entrance on the south side, which completely pinched out the seam. When this was passed, however, the seam resumed its average size. Some small step faults of about three feet fall occur locally. They mine three feet six inches of pure coal, and leave a foot of bony coal next the roof. The latter is of a massive sandstone, and unusually good, requiring but a few short "stulls" to sustain it. In places where the coal has been worked out, these are slowly crushing. The floor is of shale. Leaf impressions are common in the sandstone. The main entry is eight feet high, six feet wide and 1,800 feet long. The track is 2 feet 6 inches wide. The coal is hard and lustrous, breaking in firm, square blocks, which show distinct cleavage faces. The dip is four degrees to the south, allowing an easy down grade for laden cars to the entrance. A side track is contemplated, four miles long, connecting with the main line. At present only development work is going on, and but few men are employed. When running full, they claim a capacity of 500 tons daily. These mines, with those of the San Juan, are the chief sources of the coal supply of the town. The coal also makes excellent coke.

This Porter seam appear to be the lowest workable seam in this group, two smaller seams, one eighteen inches and another two feet, occur below, above it are three other seams, two of



which, the Peacock and Graden, are being developed. A section of the mine beginning from below upwards is as follows:

1. Massive basal sandstone in bed of creek with fucoidal fossils.
2. Coal, two feet ;
3. Sandstone, ten feet ;
4. Coal, eighteen inches ;
5. Sandstone, eighteen feet ;
6. Porter coal seam, three feet six inches ;
7. Sandstone, ten feet ;
8. Coal, two feet ;
9. Sandstone, ten feet ;
10. Peacock coal, five feet ;
11. Sandstone and shale, seventy-five feet ;
12. Graden coal, four feet ;
13. Sandstone, 100 feet, forming the top of the hill.

In the last foot of the Peacock there is about an inch of shale and a little bone in the Graden, these seams are only partially developed.

#### THE SAN JUAN COAL MINE.

This mine is located near the junction of Lightner creek and the Animas. The openings are near the summit of the great hogback, which overhangs the town of Durango on the west, and the works, with their long gravity tramway, are a conspicuous object from the city, perched, as they are, near the top of the steep slope of the hill, 600 feet above the river. The seams are apparently a continuation of those we have described at the Porter mine. A self-acting gravity tramway, 2,600 feet long, brings down the coal from the mine and discharges it at the base of the hill near the coke ovens, and not far from the Rio Grande railway. The tunnel, the opening of which we see from the town, cuts entirely through the top of the hogback, from daylight to daylight, following the dip of the seam, which is about nine feet in 100. The length of this main tunnel is 1,400 feet. From this, side tunnels are run off, varying from 300 to 500 feet in length. The mine is worked by the "room and pillar" system, instead of the "Long-wall," which is usually adopted for small



seams. The tunnels and rooms are of necessity low, owing to the narrowness of the seam, which is but four feet thick. The coal is of a superior quality, makes excellent coke, and supplies a large proportion of the local trade with coal for domestic and other purposes. The roof of the coal seam is of shale, with sandstone above it. The dip is from three to four degrees to the south. The present advantage of this mine is its proximity to the city and railroad. The capacity is about 200 tons per day, though at present they are taking out 100 tons. There is no fire damp in this mine, as the coal is high above water level and the seams are well exposed to the air, where they outcrop on both sides of the hogback.

There are some three or four other coal seams on the property, as at the Porter, which are not at present developed. In 1885 the Inspector's report gives 3,500 tons as the product for that year.

In the valley below near the discharging point of this mine is a small coking plant of a dozen beehive ovens for the use of the local smelter. The Porter, San Juan and other mines of this district send some of their coal to be coked, at this plant, and the results appear to show that a coke of superior quality is to be obtained from the coals of this region. In appearance the coke is bright and remarkably firm for Colorado coke. We predict that it will be a favorite in the market, and will have a wide instead of a restricted local use.

#### CARBONERO COAL MINE.

This mine is located two miles south of Durango, along the Rio Grande railway, and close to the bank of the Animas river. The openings are upon what used to be called the great mammoth seam, from a false impression that the body of coal formed one enormous seam, eighty to ninety feet thick. This great body of coal, however, rather consists of a number of separate seams, which, at this point, come very close together, the thickest of them not being more than seven feet. These seams are separated from one another by numerous narrow belts of shale, bone and sandstone. The strata seams are uptilted to thirty or thirty-five degrees, and the main tunnel cuts through all the various seams



across the angle of dip, a complete section being thus afforded, of which the inspector gives an accurate description from careful measurements in his report of 1886.

1. At the base of the series of seams is a floor of sandstone 100 feet thick.

2. On this rests five feet of coal.

3. 150 feet of sandstones and two feet of coal.

This lower group may correspond to that at the Porter and San Juan mines.

4. Then fifty feet of sandstone.

5. Twenty-one seams of coal from a few inches to seven feet in thickness, separated from one another by seams of shale, bone or sandstone from a few inches to three feet thick, while about the center of the group a belt of sandstone six feet thick occurs. Of these twenty-one seams about six are workable, being from four to seven feet thick, the seven foot seam is near the base of this upper series. The other seams are respectively five feet, six feet, four feet, six inches, five feet, six feet. The cap is of sandstone fifty feet thick. Thus this upper group gives us seventy-five feet of coal, and if we add to it the lower group we have a sum total of eighty-three feet.

This coal gives off a great amount of explosive gas, probably owing to its being so near to water level, for the same seams higher up in the hogback at the La Plata mine are quite free from it, proof of which is given by the fact that some old workings at the La Plata, though lying idle for years show no signs of it. In our examination of the Carbonero which was made under considerable difficulties owing to the suspension of work for some time, we noticed in the water that covered the track, bubbles of gas constantly arising, from which it is probable that the source of the gas is in the floor of the seam. A powerful current of air has to be kept up to counteract this gas and render the development safe. The coal of this mine when taken from individual seams is of good quality and yields excellent coke, but if the whole body of coal is worked together a great amount of bone and shale is unavoidable mixed with it. A main advantage of this mine is its situation on the line of the Rio Grande railway.

In 1885 the Inspector's report shows that for that year it was the largest producer in the district, its output being 5,900 tons.



The coal is softer than that of the Porter and San Juan. The softness of this great body of coal as compared with the surrounding sandstones has caused it to yield more readily to erosion, and the result is a little valley in the hogback which can be followed for miles with a wall of coal outcrops on one side and a sloping sand floor on the other. We might follow this valley for five miles, noticing on the way the individual seams now coming together and again standing apart until we reach the next important mine on this belt.

#### THE LA PLATA COAL MINES.

These mines are located on both the Carbonero and Porter belts, but at a higher point above the water level. They are in the great hogback, about three miles in a direct line from Durango, and about six by the present wagon road.

The seams of the belt have here separated into more individual relations, being sometimes many feet apart, and so can be worked singly without any great admixture of shale from too numerous partings. Two of the large main bodies, embracing in themselves some of the smaller seams, have, however, several partings, but distinct enough and with sufficiently large bodies of pure coal between them to allow of working them free from the partings. These bodies are from fifteen to twenty feet thick, but the lower portion of them is generally too much split up by shale to be worked profitably. The belts upon which this mine is opened appear to embrace most of the seams known to exist in the Durango district, both those of the lower or Porter belt, and those of the upper or Carbonero. This mine is, consequently, a comprehensive one. The tunnel, as it pierces both groups, encounters a seam at the end very like that of the San Juan in size, character and quality. The greater size of the coal bodies in this mine, as compared with those in the mines on the smaller seam group, allows more roomy and easy development and cheaper mining. The other mines have some advantages in nearness to the town or to the railroad track, but a branch line is contemplated from the La Plata to the Rio Grande track three miles distant.

The amount of coal on this property is enormous; it is also a coking coal. The coal seams are traceable the length and



breadth of the property. An outcrop of the belt in a ravine about half a mile east along the hogback shows a seam of coal twelve feet thick with only two partings, this coal appears to be hard and of a semi-anthracitic character. It was not sufficiently developed to take samples of it, but I was assured that it would not coke; such a change in so short a distance in the quality of the coal from coking to non-coking is remarkable. The redness of some of the sandstones near this coal suggests that this change may be the result of local combustion at some early date.

The openings on this young mine consist of a tunnel which has so far reached 116 feet but has in that distance cut through four important bodies of coal, three of which have been named respectively the Peacock, the Jumbo, and the Fairmount, all large bodies, while at the end of the tunnel a small seam of hard and very good coal is found, which, from its apparent correspondence with the Porter seam is called the Porter La Plata, or tunnel number three seam. As the tunnel is carried further, they will strike some other seams of the lower group, one certainly five feet thick which lies immediately upon the basal "fucoidal" sandstone composing the floor of the coal and the massive cap of the hogback. They intend to develop this mine by the Long-wall system, an unusual one for Colorado for seams of so large a size. The present main tunnel is high and roomy with a broad gauge track adapted to connect with the projected branch railroad. The company is the La Plata Coal Company of Durango, managed by Mr. F. O. Blake of Durango and Mr. Atkins of the Colorado Savings Bank of Denver.

The following is a description of the seams encountered in the tunnel beginning from the entrance :

#### JUMBO SEAM (OR TUNNEL NO. 1 SEAM).

This seam is fifteen feet thick.

Solid coal next to roof . . . . .	3 feet 6 inches
Shale parting . . . . .	8 inches
Solid coal . . . . .	3 feet 6 inches
Shale parting . . . . .	1 foot
Solid coal . . . . .	5 feet

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Workable total . . . . . 12 feet



Below this are some six feet of small seams and partings which are not workable. The coal of this seam is rather harder than that of the others.

FAIRMOUNT SEAM (OR TUNNEL NO. 2 SEAM).

This seam, a few feet below the last, is about twenty feet thick.

Solid coal next to roof . . . . .	4 feet
Shale parting . . . . .	3 inches
Coal . . . . .	2 feet
Shale parting . . . . .	2 inches
Coal . . . . .	4 feet 8 inches
Parting . . . . .	8 inches
Coal . . . . .	3 feet
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Workable total . . . . .	13 feet 8 inches

Below this, also, are some seams and partings not workable at this point, but at the old abandoned tunnels they join, showing workable size and less shale.

PORTER-LA PLATA SEAM (OR TUNNEL NUMBER 3 SEAM.)

Seventy-two feet from the last near the end of the tunnel is four feet six inches thick of nearly clean coal.

Solid coal next to roof . . . . .	1 foot
Clay parting . . . . .	1 inch
Solid coal . . . . .	3 feet 6 inches
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Total . . . . .	4 feet 6 inches

DESCRIPTION OF FRONTISPIECE PLATE I.

The scene depicted in the frontispiece is from the top of the hogback above this mine, from which we have a splendid panoramic view of the region for hundreds of miles, over which by the color and relative position of the rocks we can trace as in a map the main geological features and structure of the surrounding country.



In the distance to the south is the plateau country of the Ute reservation, the strata of which are mostly of Tertiary age composed of rusty sandstones and variegated clays. The course of the Animas may be traced winding like a silver thread among the mesas and passing through a gap in the horizon. To the west, a large area is occupied by uplifted Tertiary and Laramie-Cretaceous coal-bearing strata underlaid by a thickness of about 1,000 feet of Fox-hill shales which are easily recognized by their drab gray color. Through this hogback country, the valley formed by the erosion of the great Carbonero coal belt is clearly seen, till it is lost in the distance or merges in the horizontal strata of the distant Montezuma valley, where in our picture the sun has just set. At the base of the steep slope of Fox-hill shales in which this hogback ends, and which, as we have explained and shown by the section, is produced by a fault of about 1,000 feet fall, begins the second bench, the cap of which is formed by gently sloping sandstones containing the lower and thinner group of coal seams, worked by the Shores, San Juan, and Porter mines. This too in turn ends in a steep slope of 2,000 feet, above the river and city, composed of Fox-hill shale capped by the basal sandstone.

Near the top of this slope the San Juan mine is shown with its long granite tramway carrying the coal down to the river-bed where Lightner creek opens into the Animas. The smoke of the smelter of the San Juan Smelting Company, with that of their coke ovens, is seen arising from the bank of the river. Following up Lightner creek, a ravine in the hogback leads to the Porter mine. A valley of erosion about a mile wide separates this hogback from its continuation in a series of castle-rocks and tables, the sandstones of which carry the same coal seams, until finally we see the coal strata uplifted against the snow-capped La Plata mountains in the northwest.

The erosion of Junction creek cuts off the coal strata on the east and reveals lower strata, consisting on top of the Dakota group, and below it, the Jurassic, and at the base the red conglomerate of the Trias. This hogback is again cut in section by the beautiful valley of the Animas river, whose waters have worn down through period after period of the uplifted strata as we



ascend the cañon, till finally bedrock granite is reached, and further on we find the whole Palæozoic series uplifted against the San Juan range and covered, together with the underlying granite by the mighty lava overflows of that wonderful and picturesque region.

The town of Durango is seen nestling in the valley of the Animas, strung out to a great distance along either bank of the river, and above it on the north rise the castle rocks with their cliffs of shale, which are sculptured into forms noticed by every visitor.

In the foreground a portion of the uplifted bench with its basal-sandstone cap, 100 or more feet thick, full of rusty impressions of fossil *Halymenites* sea weeds underlaid by the Fox-hill shales is shown. This forms the great sloping floor for all the coal belts, hence the first valley above it to the left is that caused by the erosion of the Carbonero coal belt, which, as the sketch indicates, is traceable across the Animas to the west, and along the La Plata property to the east. Immediately below us are the workings of the La Plata mine, and the little ravine running south along the course of the creek is the projected line of the branch railroad to the main Rio Grande track whose line is visible in the middle distance.

The next valley and ridge has a stratum of fossil shells in it but no coal seams, and from thence to the next purplish ridge and beyond, no more coal is found, as the strata probably belong to an upper series or to the Tertiary. The accompanying geological section shows the leading features of the geology of the district, and the small side sketch the workings of the La Plata mine and the well marked outcrops of the great coal seams.

From the top of the hogback we look down on the second bench which has been faulted down, and can trace its connection with the San Juan ridge on the other side of the Animas. In this lower bench we notice the City Bank, Black Diamond, and other mines on the San Juan small seam; as these mines were not working at the time of our visit we could not properly examine them.

It is seldom that a geologist has an opportunity of obtaining so wide a panoramic view, in which so much beautiful scenery is combined with such an easy and comprehensive reading of the



geological features of the country, or of delineating so vast a coal field with such large seams of excellent quality.

Analyses of coal from the Durango district by Professor Geo. C. Tilden.

### PORTER MINES.

#### PORTER SEAM NO. 1.

Water . . . . .	.63 per cent.
Volatile matter . . . . .	34.70 "
Fixed carbon . . . . .	57.30 "
Ash (brown) . . . . .	7.37 "
	<hr/>
	100.00

Sulphur . . . . . 0.737 per cent.

#### PEACOCK SEAM NO. 2.

Water . . . . .	2.49 per cent.
Volatile matter . . . . .	34.31 "
Fixed carbon . . . . .	51.98 "
Ash (gray) . . . . .	11.22 "
	<hr/>
	100.00

Sulphur . . . . . 1.68 per cent.

#### GRADEN SEAM NO. 3.

Water . . . . .	2.94 per cent.
Volatile matter . . . . .	35.63 "
Fixed carbon . . . . .	50.65 "
Ash (light yellow) . . . . .	10.78 "
	<hr/>
	100.00

Sulphur . . . . . 1.53 per cent.

### SAN JUAN MINE.

Water . . . . .	1.12 per cent.
Volatile matter . . . . .	37.30 "
Fixed carbon . . . . .	54.69 "
Ash (light brown) . . . . .	6.89 "
	<hr/>
	100.00 "
Sulphur . . . . .	0.864 "



## CARBONERO MINE.

Water. . . . .	1.16 per cent.
Volatile matter. . . . .	34.33 "
Fixed carbon. . . . .	52.69 "
Ash (gray). . . . .	11.82 "
	<hr/>
	100.00 "
Sulphur . . . . .	1.22 "

## THE LA PLATA COAL MINES.

FAIRMOUNT SEAM (UPPER SECTION 4 FEET 8 INCHES THICK).

Water. . . . .	1.21 per cent.
Volatile matter . . . . .	39.72 "
Fixed carbon. . . . .	51.02 "
Ash (white) . . . . .	8.05 "
	<hr/>
	100.00 "

## FAIRMOUNT SEAM.

Lower section of seam four feet six inches thick.

Water. . . . .	1.30 per cent.
Volatile matter . . . . .	39.70 "
Fixed carbon. . . . .	54.78 "
Ash (light red) . . . . .	4.22 "
	<hr/>
	100.00

## PORTER-LA PLATA SEAM OR TUNNELL NO. 3.

Water. . . . .	1.11 per cent.
Volatile matter . . . . .	36.54 "
Fixed carbon. . . . .	51.69 "
Ash. . . . .	10.66 "
	<hr/>
	100.00
Sulphur . . . . .	1.450 per cent.







## CHAPTER VIII.

# Coal Fields of Northwestern Colorado.







## CHAPTER VIII.

### COAL FIELDS OF NORTHWESTERN COLORADO.

#### GEOLOGICAL NOTES BY THE WAY.

To examine this district we took the Midland railway from Denver via Leadville to Glenwood. The Colorado range, the South Park and Park range were crossed in the night, and early morning found us at Leadville. The train took us a few miles up the wide Arkansas valley, and then turned off to the left or westward into the Sawatch range up Lake creek cañon. The Palæozoic quartzites and limestones of the Leadville series are seen for a short distance up the Arkansas valley dipping to the east, off from the granite, with a few mine openings in them, and then for many miles as we go west all is Sawatch gray granite, showing evidence of former glaciers by numerous moraines, polished and striated rocks and U shaped cañons, until we cross the continental divide and go down into the valley of Frying-pan Creek. Near Lime Creek station (Calcium) we meet the first signs of sedimentary rock on this side of the Sawatch range; they are Palæozoic quartzites and limestones dipping to the west off from the granite axis, at an angle of from 30 to 50 degrees; resting on these is a thickness of several thousand feet of gypsiferous shales belonging to the Upper Carboniferous, followed above by fine grained red-sandstone of the Triassic. The dip of these is at first steep and to the west, but as we go down the creek, it gradually begins to flatten out, and as we approach the Roaring Fork valley the dip again rises gently in a contrary direction to the east, hence a wide shallow synclinal trough is formed between Roaring Fork and the Sawatch range. The red sandstone being in many places of excellent quality is extensively quarried for building stone, not far from Aspen Junction along the Midland route.

Near Aspen Junction the hills are covered with a dark, vesicular basalt which overwhelms large areas of this district and is evidently a surface flow of comparatively recent date.



As we go north down the Roaring Fork valley in the direction of Glenwood, the east banks are composed of red Triassic sandstone upwards of 1,000 feet thick, dipping east 45 degrees, and west on the other bank, forming a steep anticlinal arch the center of which has been eroded out to form the present river beds of the valley. Beneath this some pale gray shaly beds appear with very black looking bands of carbonaceous looking material; these lower beds show by their relation to the Trias above them, that they belong to the Upper Carboniferous. Some limestones and gypsum occur in them.

This folded anticlinal and synclinal structure is due to the influence of the Elk mountains on the west, crushing and folding the strata intervening between their eruptive masses and the Sawatch range. One of their majestic, volcanic peaks, Mount Sopris, appears prominently on the right, to the southwest of us. Along the northern and western base of this mountain, removed from it by erosion for some miles, circle the coal hogbacks of the Jerome park basin among which are the coal mines of Sunshine, Marion, and Spring Gulch, and beyond them still further west, those of Coal Basin. The little town of Carbondale is located in this district near the junction of Rock Creek with the Roaring Fork. A few miles further we pass through Cardiff, the main outlet and coking station of these mines, and descend into the valley of the Grand river where the pretty town of Glenwood is located at its junction with the Roaring Fork.

#### GLENWOOD.

The Grand river just east of the town, issues from a deep cañon in Palæozoic rocks, folded over Archæan granite; this granite is of a reddish color containing very large crystals of orthoclase feldspar, often six inches in length. The dip of the sedimentary rocks some way up the cañon is as much as 45 degrees to the west, diminishing gradually to 25 degrees near the entrance; the strata are thrown into gentle wavy folds accompanied by faults, as it bends down from the steep to the shallow dip of the anticlinal fold. The Grand river issues from this canon in the Cottonwood range, (part of the White river plateau), as a broad, fast-flowing stream of beautifully clear water. After its



exit from the main cañon and union with the Roaring Fork its course is through a deep valley cutting diagonally across the strike of all the sedimentary series shown in that neighborhood; in this way we have exposures of the Red-beds, the Dakota, and the Laramie coal beds, the strike of the latter running approximately northeast and southwest parallel to the course of the river. At Newcastle, some twenty miles north of Glenwood, the river takes a sudden bend and cuts through the coal hogbacks across their dip, exposing an admirable section of the entire Laramie group with its many contained coal seams. From the coal hogbacks it emerges on to a prairie country diversified by plateaus of Tertiary origin, and passes out of sight by entering a cañon in the Book Cliff plateau, a series of lofty table lands that bound the southwestern and northwestern horizon.

#### THE HOT SPRINGS.

On our arrival at Glenwood we visited the far-famed Hot Springs, situated on the shore, banks, and even in the bed of the Grand river. The principal ones are found at the outlet of the cañon and occur at intervals of a quarter of a mile down the river, and a half a mile up the river in the cañon. The largest and most utilized are on the north bank of the stream; the springs doubtless issue from deep-seated fissures penetrating through the Palæozoic rocks down into the granite beneath, and emerge through the overlying pebbles and drift of the river as through a seive, which disseminates the water into hundreds of miniature springs bubbling up fiercely in the center of pools varying from the size of a saucer to many yards in diameter. The springs, small and great, throw up fountains of sand into their pools, from the force of the carbonic acid gas, which violently disturbs the surface of the pools in escaping. Some of those which come up with great force and volume, are artificially enclosed in wide, circular reservoirs of red sandstone. Quite a number of these reservoirs have been built to retain the water for swimming baths. As the water is too hot for bathing, it passes off by a sluice into a capacious tank or swimming bath where it is cooled to a moderate temperature. The water in the hot reservoirs is invisible from the amount of steam given off, but through



riffs in the stream, appears of a delicate metallic blue, the steam being of the same color, though fainter.

The dense volume of steam rising day and night from these natural caldrons, is a striking spectacle on entering the valley, particularly when illuminated by moonlight. The temperature is about 124 degrees Fahrenheit. Notwithstanding this great heat, we notice a species of green water-weed, of a low order of cryptogamia, belonging to the "confervoideæ" family, of a dark olive-green, ascending from below in long, soft, semi-gelatinous ribbons, or floating free on the surface in spongy masses. These plants collect around them much of the solid chemical precipitates of the water, such as soda, lime, salt, and are used by rheumatics to rub themselves down with after a bath. Carbonic acid gas is copiously discharged from these springs, and in part gives the force to the bubbling ebullitions. Sulphuretted hydrogen is also present and gives a taste to the water, but not to a noxious extent. From analysis it appears that the main components outside of these two gases are common salt, gypsum, carbonates of magnesia, soda and lime, and silica.

Besides these active springs there are evidences over quite a large area, of former hot-spring action, now extinct. The drift pebbles forming the banks of the stream are firmly united in many places into a coarse conglomerate by a calcareous cement, and by calcareous tufa and travertine, mixed with iron oxide and other incrustations, due to hot mineral waters. The clays of the banks above the springs show brilliant colors of red, purple and maroon tints, from oxidation of iron. The same effects resulting from ancient thermal springs, have produced the wonderful coloring in the Yellowstone cañon of the National park. A magnificent \$250,000 hotel and bath house of red sandstone has been constructed by the Midland railway over the springs.

The hotel is to be equipped with most elaborate bathing accommodations for what is expected to become a world-wide resort.

From this principal area of mammoth and dwarf springs we followed the railroad track up the cañon; for some five hundred yards or more we noticed signs of springs, active or dead, some close to the river, others on the banks, and some on the cliffs



above the river. Those in the river are bubbling up, and in most cases are surrounded by small cisterns of masonry, others steam out from the pebbles of the bank, the steam of others can be seen issuing from fissures in the limestones above the river, on the walls of the cañon. For many yards we observe in the massive limestone (which appears near the entrance to have been considerably disturbed and has fallen in massive blocks), numerous vertical fissures on jointing planes enlarged at various points by small caves and holes, coated with calcareous tufa, small stalactites, and other evidences of former hot-spring action. The extinct fissures in the cliff above appear to correspond with the line of active springs in the river bed below, and both the line of fissures and the springs located upon them, appear to cross the river and coincide on either bank.

Just at the entrance of the cañon and before reaching the massive limestones of the cañon walls, we pass through beds of a shaly character belonging to the Upper Carboniferous; the Lower Carboniferous limestones dip under them at an angle of twenty degrees. These limestones are exceedingly massive and homogeneous, so much so, that it is hard even to detect signs of lamination, still less those of stratification, and as it is cleaved in a remarkable way, not merely by the deep and tolerably wide fissures of ordinary jointage at some distance apart, but in places by cleavage lines, so close together as almost to resemble those of slate, we are apt to mistake these vertical lines of cleavage for the real lines of bedding. Thus we might at first sight imagine the strata to be standing on edge vertically, instead of in reality dipping from 45 to 20 or even 15 degrees to the west, as is clearly shown further up the cañon where the lines of bedding are distinct. This massive limestone from its characteristics and position relative to thin bedded drab Silurian limestones below it, and the Cambrian quartzites below that, which rest on the granite, we assume to be Lower Carboniferous, the same series which at Aspen and Leadville contains the silver-lead deposits.

These vertical cleavage fractures have been enlarged by water, and widened into narrow caverns encrusted with calcareous tufa and stalactites of aragonite. There are some twenty or thirty of these more prominent cave fissures within a horizontal distance of



500 yards from the entrance of the cañon, and their origin, and relation to hot springs, is clearly shown when we enter the Cave Bath house.

This is a bath house erected over one of the hot springs which sends up its steam and hot air through a natural fissure above it, which by this action has been eroded and enlarged into a cave large enough to allow a dozen persons to sit in nature's garb upon benches cut in the stone sides, and there be thoroughly steamed in a natural Russian bath. The fissure penetrating the rock is about fifty feet in length, and doubtless continues on as a mere crack for an indefinite distance. You enter the cave by a sort of passage way, across which a flap door is thrown, the heat appears at first unendurable, but you soon become accustomed to it, and your body breaks into a profuse perspiration. The sides of the cave are hollowed out here and there into smaller cavities, and these, together with the walls, are coated with travertine and other incrustations, which are wet and dripping with the condensing steam. After about a quarter of an hour in this steam bath, you emerge from the cave, take a tepid shower bath, dress quickly and walk briskly home, well wrapped, with a consciousness that every possible impurity is removed from the outer pores of your skin. The cave has been and is still being formed by the ascending steam of the hot springs below, of which, probably, at one time it was also the channel before the erosion of the river had reduced the position of the springs to a lower level on the line of fissures.

We are reminded here of certain theories as to the origin and filling of fissure veins; we see heated water charged with mineral solutions, such as lime, soda and sulphur, held in suspension in the vapor, chemically eroding and enlarging a natural fissure, and depositing upon its cooler surface, these elements by precipitation, in layer upon layer, as we find in the peculiar ribbon-structure arrangement of the gangue and minerals in some fissure veins.

The abandoned caves and fissures are, many of them, partially or completely filled with these crystalline deposits, and doubtless some of the smaller crevices would be found to be true veins filled with ribbon-structure calcite.



## PROBABLE ORIGIN OF SPRINGS.

The remote origin of the hot springs is doubtless in some fissure, deep enough to reach the buried heat of the earth, ever increasing as great depth is attained. Such a fissure was doubtless formed in the process of folding up and elevating the mountains, the evidence of such dynamical forces together with the extrusion of volcanic rock in a molten condition, are peculiarly strong in all this region. We looked for evidence of such a fault or fissure at this exact point, but could not find positive proofs of such an occurrence, though the broken up appearance of the rocks, and the parallel cleavage structure at the entrance of the cañon, was suggestive of the proximity of some great faulting or crushing movement. I am inclined to think that the springs occur just at the point where the anticlinal of the Roaring Fork, which we have already noticed, bends down into a sharp synclinal before the strata are again uplifted into the anticlinal of the Cottonwood range, such a sharp bend would be likely to be accompanied by faulting, and also by that singular compression, of which the cleaved limestones at the entrance of the cañon appear to give evidence.

As to the depth of the fissure, assuming an average increase of heat of one degree for every 50 feet, we should have the present heat of the springs at about 7,000 feet, and many fault-fissures are as deep and deeper.

Another hypothesis for such highly heated waters may be, that in the folding and crumpling of the rocks to which this region has been peculiarly subjected, great mechanical heat was engendered, which still lies dormant at great depths. Surface water penetrating through deep fault cracks would be heated and rise to the surface by hydrostatic pressure as well as by force of steam and the carbonic acid gas held in suspension.

Lavas again of modern volcanoes are known to retain their heat at some distance below the surface for an enormous time after that surface has cooled, and to give rise to such phenomena as geysers or hot springs, by surface water percolating through fissures down to them. We observe no true lavas, ancient or modern, in direct connection with the springs, but the hills around



are covered with comparatively recent basalt, and we have about fifteen miles from this center, the remains of a true crater, and a very recent lava-flow at Dotsero, which we shall presently describe. For further evidences of eruptive action on a grand scale we have but to look at the magnificent volcanic cone of Mount Sopris, whose extrusion, together with that of the whole Elk Mountain range, seems to have exerted a wide influence on the dip and contortions of the strata, as well as on the partial metamorphism of the rocks of the region. Mount Sopris and other Elk Mountain peaks are vast reservoirs or "laccolites" of molten rock from which the strata that once folded over them, as the volcanic matter was intruded into them, have been eroded away, revealing the intense volcanic forces that have been active in this region. So as hot springs are generally found in regions of volcanic and dynamical disturbance, we are not surprised to find them at Glenwood nor should we be surprised to meet with them at various other points in the Elk Mountain region

#### GEOLOGY OF COTTONWOOD CAÑON.

Continuing our walk up the Cottonwood cañon we pass down (geologically) from the massive gray Carboniferous limestone to thin bedded drab limestones of the Silurian and thence to Cambrian quartzites, and finally through Archæan granite. The Palæozoic strata rise tier upon tier to a height of many hundreds of feet, displaying a considerable thickness, and are seen to gradually arch over the top of the mountain. As we continue onward, the faults become greater as we reach the axis of the range, and at times the Palæozoic rocks are uplifted to a great height on a steep fault-cliff of granite. As we emerge from the cañon on the east side, the structure of the folds is similar to that on the west, gradually dying out on the flanks and giving place to a bluff country of Upper Carboniferous strata composed of variegated gypsiferous shales capped by the red beds of the Jura-Trias dipping easterly. We are now in the valley of the Eagle near its junction with the Grand, and stop at Dotsero station, our object being to examine the remains of an extinct volcanic vent and comparatively recent lava overflow of which numerous accounts had reached us when at Glenwood.



## THE DOTSERO VOLCANIC VENT.

The valley of the Eagle between the hills is from one to two miles in width. About a mile east from the station the river hugs the south edge of the steep face of the hills. At this point a very black looking rock covers the meadow of the valley, spread out in a fan shape like a large pancake over an area of a square mile. The edge of the cake ends abruptly near the base of the cliff forming the south bank of the river, the latter cutting through it and separating it from the cliff beyond. As there was no bridge we waded the stream and ascended the opposite bank. The bank proved to be a rugged cake of lava over fifty feet thick. The central portion was of hard, massive, dark gray basalt showing a fluidal structure and a few small steam holes. Above this were masses of scoria piled up and tumbled along in chaotic confusion like furnace slag. Underneath the solid portion the lava was also scoriaceous. It resembled pictures of the recent lava flows of Mauna Loa or Vesuvius. The blocks of "scoria" were as vesicular as honey combs. The edges of the little circular steam holes were as fresh and sharp as if the flow had occurred but a week before, and were not filled by zeolites or amygdaloids as is the case generally with basaltic flows of an older date. The surface of a greater part of the flow is destitute of vegetation, one black, rugged mass of slag and clinkers. Toward the opposite side of the valley decomposition has allowed a sparse covering of grass and sage brush.

I had no difficulty in tracing the flow across the valley to the entrance of a narrow ravine in the hills. Great rugged masses of scoria were adhering to the sides of the ravine as though a furnace had lately poured molten iron down it. Erosion had removed the lower portion of the lava and bitten into the sandstones forming the bottom of the ravine. Following up the gulch for about a mile into the hills, the lava flow became thicker and more continuous, and appeared eventually to issue from a huge semi-circular bulging mass on the top of a hill of very steep, smooth outlines. This hill, with all the surrounding hilltops at this level, for a circular area of about a mile in diameter, is composed or covered with grey "lapilli," little fragments of scoria, shale and red sandstone, from



the size of a pea to that of a hen's egg, shot up by steam from the throat of the volcano, and falling in showers around the vent. These beds of "lapilli" appear to be of considerable thickness. Near the top of the hill they seem to have been consolidated into a coarse stratified "breccia," tipped up at an angle of 5 or 10 degrees on either side of the great mass of lava, as though the latter had broken through this portion of the crater and tilted up the brecciated sandstone of its wall in its exit.

Climbing over the lava mass, I stood on the top of the hill and looked down into a perfect, oval-shaped crater, the bottom of which lay between 600 and 800 feet below me. The walls of the crater are of red triassic sandstone between 500 and 800 feet deep in the steeper part, while from the top of the lapilli-covered hills, sloping gradually down into the steep throat of the crater, the height was over 1,000 feet; the crater may thus be said to be about 1,000 feet deep.

The bottom of the crater is oval and comparatively flat, dipping, however, some five or more degrees to the south, that is, towards the side where the lava seems to have broken through and poured out. The diameter of the bottom is between 200 and 300 yards, the surface is covered with debris and sage brush, doubtless overlying a solid plug of congealed lava. The width of the crater on the top of its steeper portion is about 500 yards. The sides of the throat are quite steep, having an inclination of from forty-five to seventy-five degrees, and it would be difficult to climb up or down. I did not make the attempt for lack of time. There is no natural entrance or exit to the crater, it is a complete cup.

The red sandstone strata forming the walls of the throat, dip inwards, at an angle from thirty to forty degrees, and appear to converge towards the center of the crater. Time only allowed me to make some rapid sketches and hurried observations, but from what I saw, I think the following may be the history of this undoubtedly true crater and volcanic vent.

#### PROBABLE HISTORY OF THE VOLCANO.

At some time, probably within the human period, eruptive forces found a vent at this point and explosions of steam blew



out a crater hole in the Upper Carboniferous and Triassic strata. That the action was explosive I judge from the great quantities of "lapilli" and continued fragments of shale and sandstone covering the surrounding hills. The steam, descending as water, worked up some of the "lapilli" into a stratified breccia around the rim of the crater. When the explosive energies that had filled the sky with clouds of steam, ashes and "lapilli" descending in showers upon the surrounding hills, had abated, a volume of lava rose in the throat of the crater, and poured out over the lip on the south side, partly breaking through the crust of breccia and tilting it up as it passed through it. From the lip of the crater the lava poured rapidly down the steep face of the hill and thence through the narrow gulch into the open valley, where it spread out as a cake over the meadows and on to the river which it must have temporarily dammed back. The force of the lava was finally checked by the abrupt cliff forming the south bank of the Eagle. The water of the stream may also have arrested its progress by congealing it. Later on, the river cut through the flow and resumed its course. The character of the lava sheet, scoriaeous and spongy above and below, massive and compact in the middle, corresponds with what is observed in modern lava flows. The surface of lava in contact with the air or water, gives off its imprisoned steam through multitudes of little steam-holes, which reduces the surface of the sheet to a rough, spongy, vesicular mass, while the liquid lava continues to flow on below until it cools in a compact body. As the molten stream advances, this spongy surface is broken up into clinkers which are rolled along on the top of the liquid stream, and falling off from the end of it, are dragged underneath it, and all together are piled up in confused masses where there is any check or obstacle to the flow such as the cliff and river in the present instance. After the extrusion of the lava the red sandstone strata collapsed inward causing the converging dip alluded to.

Exactly how old or recent may be the date of this eruption, it is not easy to determine. There are tall fir trees growing in the crater, and thick sage brush on the bottom. I did not see any signs of springs or emanations of gas in the vicinity, such as are common in recently extinguished volcanoes, nor are volcanic rocks particularly abundant in the immediate neighborhood,



The occurrence seems rather an isolated one. This interesting locality is accessible by the morning train of the Rio Grande railroad between Leadville and Glenwood. The lava flow is just across the river close by the track, but the crater is between three and four miles back to the north in the hills. The blue-gray "lapilli" capping the hills can be distinctly seen from the train and mark the site of the volcanic vent.

#### THE NEWCASTLE DISTRICT.

Returning to Glenwood we followed the course of the Grand down through a narrow valley in a northwest direction, toward the coal mines about Newcastle. Soon after leaving Glenwood the river cuts through a great thickness of red Triassic sandstones, then through the sandstones of the Dakota Cretaceous, and (as we near Newcastle) along the strike of the Laramie coal group, which forms the western bank of the stream by a very steep hogback, 2,000 feet high. The first coal opening we pass on the side of the track is the Pray mine; further on we enter the valley formed between the great hogback of the Laramie on the west, and by a lower hogback of the uppermost member of the Fox-hills group on the east.

Looking up the face of the almost perpendicular cliff we notice at intervals several prominent beds of sandstone, with softer shaly beds between them, the outcrops being more conspicuous and closer together towards the upper 500 feet of the cliff, and corresponding to some seven or eight different coal seams, dipping with the hogback about 50 degrees to the west. About 1,000 feet up the face of this cliff, the tunnel of the Elk Mountain Fuel Company is driven through the hogback a distance of 1,000 feet, exposing in its course a complete section of the strata and of the principal coal seams in the upper portion of the hill. Two or three miles more brings us to Newcastle, a small town of about one hundred houses, located on the east bank of the river on a flat between the two hogbacks. The railroad spans the river with a fine iron bridge, and passes through the town to the Newcastle coal mine, located about half a mile beyond the village, at a point where the Grand river makes a sharp turn to the west, cutting the Laramie hogback in two. A



complete transverse section of the entire Laramie group with all its enclosed coal beds is thus exposed.

The coal mines are in prominent view from the village. Looking toward the gap we see three openings near the base of the hogback a little above the level of the river, and three more on the dip of the strata; these openings at short intervals from one another, represent three large coal seams. The first and uppermost seam, "D," is five feet thick, the next seam, "E," or the "Wheeler" seam, at an interval of 100 feet from the last, is forty-five feet thick, and the third or "F" seam, eighteen feet from it, is sixteen feet thick. There are several other seams above and below these of more or less workable size, but these three seams are the only ones at present developed, and that not to a considerable depth, as the mines are in their infancy, being but a few months old; of the six tunnels the three lower ones average about 500 feet each in length.

The peculiarity of the five foot "D" seam, is the extreme dryness of the coal, which is also hard and compact, showing but little signs of cleavage or "butt and face" structure. It is on this account a little hard to work, but is of excellent quality, not slacking on exposure, as proved by fragments of coal that have lain on the surface for years, and which show no alteration or influence of the weather. This is the hardest coal in this portion of the hill.

It was in this tunnel that a fatal explosion occurred some time ago, which is generally attributed to ignition of the coal dust after a blast had gone off, this dust when it accumulates being highly inflammable and explosive. To prevent similar accidents, a hose of running water is kept in constant use in all these mines to lay and moisten the dust as fast as formed. That the dust was the cause of the accident is clear from the total absence of any gas in the mine.

The dip of the coal seam is about fifty degrees to the southwest. The tunnels at the base of the hill pass horizontally into the strata along the strike, stopes being worked upward with a height above them of about 1,000 feet. The roof of the seam is of massive sandstone, and so far has not required much timbering.

The adjoining great Wheeler "E" seam, forty-five feet thick, is also developed by a horizontal tunnel. Owing to the great



width of the seam, four feet of coal can be left to support the roof. The coal is softer than in the five foot seam, and considering the unusual thickness, remarkably pure, only a few thin partings of shale being found. This is the largest seam of pure coal so far discovered in Colorado.

The adjoining seam "F," 18 feet from it and 16 feet thick, is of very similar character. There are some slight indications of gas in these two seams and more may probably be encountered, when greater depth under the mountain is attained. In the present small development the tunnels give good enough ventilation, which will be increased by cross-cut tunnels uniting the main entries. At the upper workings an upcast shaft is in process of construction, which will be supplied with a fan. The two seams being so near, the tracks from their tunnels unite in a main track running out on to a tippie, from which the coal is dumped into the cars of the Midland railway.

From the lower workings we ascend to the upper ones on the same seam, over a double incline tramway 500 feet in length with double tracks, on which ascend and descend by gravitation the laden and empty cars, an ingenious contrivance attached to one end of the car, automatically setting the car free from the guide rope the moment it touches the platform of the tippie, thus dispensing with much of the labor involved in hooking and unhooking the cars. At the top of the incline the three seams are again well exposed by an open cut, and by short developments on the seams themselves. Above the coal seams we notice a slight depression or sag in the hill, where the shaly or more pliable strata immediately overlying the coal seams, have been puckered into a series of small folds. This was caused by fire in the coal seams at some unknown period, the coal having been burnt out to some depth below the surface, causing the overlying strata, by collapsing, to be thrown into the folds we have mentioned. The strata in the neighborhood of the coal seams have also been partially metamorphosed by this combustion for many miles along the outcrop and for several hundred feet in width. In the coal seams in these upper workings, the coal near the surface, and to depths not yet determined, has been reduced to a species of anthracite. Immediately over the coal is a belt of



smut a few inches thick, then pure white calcined clay, like fire-brick, followed by red and yellow calcined shales. The surface all along the strike of the hogback for many yards on either side of the coal seams is of a red color. In fact both in the Newcastle region, and also in the Sunshine district, some twenty miles distant, the presence of the coal beneath can often be traced on the surface by the redness of the strata. We were told that in part of the workings of the Newcastle mine they were unable to work, owing to the heat, and, although there is no present sign of active combustion, either in the form of fire, smoke, or noxious gases, yet some two or three miles to the north, along the same set of strata, the coal is actively burning, as evinced by clouds of vapor issuing from the ground, which can be seen at a considerable distance. There is a tradition that years ago old-timers saw the area now worked for coal similarly ignited, and if so, it would seem that the fire has burnt out in this area and continued its combustion along the hogbacks, more in a north-westerly direction. We have at present no evidence to prove how deep below the surface the fire has penetrated. That the heat must have continued slowly for a long time, seems implied by its metamorphic action on the surrounding strata, and the upper portion of the coal seam, such processes being attributed usually to long continued slow heat, rather than to violent or active combustion.

About one hundred feet above the upper workings is a red looking mass of rock resembling a volcanic breccia. This consists of shale and sandstone, metamorphosed into a hard red jasper with clinkers here and there coated with red molten material, the cavities in the breccia being lined with downy crystals of gypsum. The mass was very much like a clinker pile outside an iron furnace. On moving some of the clinkers we found the interior of the mass perceptibly warm, showing the strong latent heat still existing in the strata. As the tunnels will pass under the hill at a depth of from 500 to 1,000 feet, it is probable they will not be troubled by encountering these burnt or still burning strata until they near the surface in stoping upwards.

We followed the coal strata to the top of the hogback about 2,000 feet above the valley. The sandstones were reddened in



the neighborhood of the coal seam to the very summit. Within a few feet of the top Mr. Thies found impressions of large leaves of a Laramie type in the sandstone. These were proof that the horizon of the coal is the same as that on the eastern foothills.

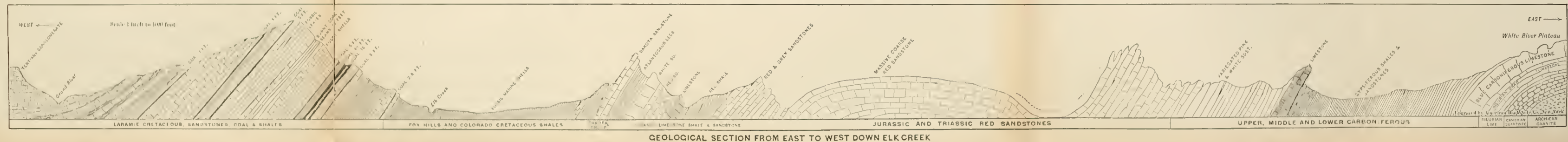
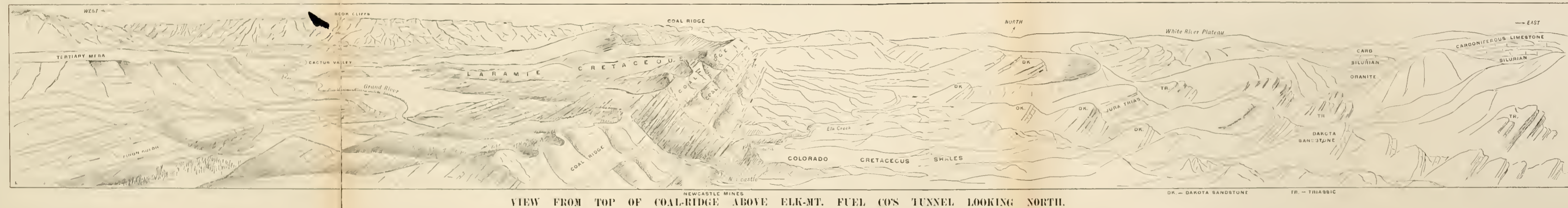
While he was collecting these fossils I climbed to the top from which there is a sublime view of the surrounding country, an idea of which I have tried to represent in the accompanying panoramic sketch (plate XIII). Looking in a southeast direction, immediately below us is the valley of the Grand river, which flows between the great coal hogback on its southwest side, and a smaller hogback of sandstone on the east side, the little village of Newcastle lying on the flat near the center of the valley. The Grand River takes a sudden turn toward the west, cutting through the great hogback, near the point where the Newcastle mines beneath us are located, it then flows for many miles to the west, passing out of sight in the cañon, in the distant Book Cliffs. The great coal hogback is the most striking object on this side, rising abruptly from the southwestern bank of the stream in a very steep slope to a height of 2,000 feet above the river bed. Over the crest of it, we see a number of low hogbacks rising in tiers one behind the other, their angle of dip gradually lessening from forty-five to twenty degrees, until the strata pass under a wide horizontal plateau. A valley occupied by a little stream emptying into the Grand, forms the dividing line between the uptilted hogbacks and the horizontal strata of the plateau, and also limits the western extension of the Laramie group with its coal bearing strata. The area between the crest of the hogback and the plateau, is called Pinon basin from the heavy growth of these dwarf pines upon the crests of the thick series of sandstones of which the Laramie group in this section is largely formed.

The strata are well exposed on the face of the great cliff above the river, and consist of a series of shales and sandstones. The more prominent and harder belts of sandstone, stand out in relief from the softer beds of shale, and in many cases represent the floor and roof of different coal seams. The shaly portion is more toward the lower part of the cliff while the sandstones congregate toward the upper part. In this upper section occur the principal coal seams, some seven or eight in number, with numerous smaller











seams. The workings of the Elk Mountain Fuel Company may be seen in the distance, toward the upper part of the cliff, cross-cutting and developing several seams by the Coal Ridge tunnel, nearly 1,000 feet long, which emerges on the Pinon basin side, letting in daylight at both ends. The sketch will give an idea of the great thickness of the Laramie group on this side of the mountains. The steep cliff of the hogback represents a vertical thickness of 1,000 feet, and the aggregate thickness of the hogbacks lying in sections back of this in the Pinon basin, 2,000 feet, giving a sum of 3,000 feet for the entire group.

The line of the principal coal seams as developed at the Coal Ridge tunnel will, we think, if protracted, carry the coal down near to the base of the hogback and cause it to pass under the river a little above the town, whence it is continued up the face of the hill to the Newcastle mines. The exact outcrop of the seams along this line are obscured by debris and vegetation.

The great hogback representing the northwestern coal field, after leaving the valley of Newcastle, swings around towards the east and south, in the direction of Rock creek and the Sunshine district for some twenty miles, continued on by the coal basin field north of Sopris peak, thence it can be traced up Rock creek towards Gothic, and then with interruptions by the eruptive masses of the Elk mountains to the anthracite and coking coal fields around Crested Butte, thence up Anthracite and Coal creeks to Irwin and beyond until it merges in the great plateau of the Grand Junction and Montrose districts. Beyond that again it can be traced to the flanks of the San Juan mountains near Ouray, that range separating it from the southwestern field in the neighborhood of Durango.

Turning a little to the left of our drawing, that is to the east and southeast, we can see at a glance the relative position of the coal group to the periods lower in the geological scale. For east of the little hogback behind Newcastle, is a flat valley, drained by the waters of Elk creek, about half a mile or more in width, and underlaid by the marine shales of the Fox-hills and Colorado groups of the Cretaceous, dipping at a steep angle; back of them rise the sandstone hogbacks of the Dakota Cretaceous, and behind them again is a great thickness of some



thousands of feet of red Jurassic and Triassic sandstones and limestones, which in turn lean upon the Palæozoic limestones and quartzites of the Carboniferous, Silurian and Cambrian series, these lastly are found in the deep cañons resting upon the Archean granite of the White river plateau system. Turning to the west, we observe the Laramie group passing under horizontal table lands of Tertiary origin, which comprise also the strata of Cactus valley and a still higher group of the Tertiary, forming the Book Cliffs in the far distance. Thus is the section complete from lowest Archean to highest Tertiary.

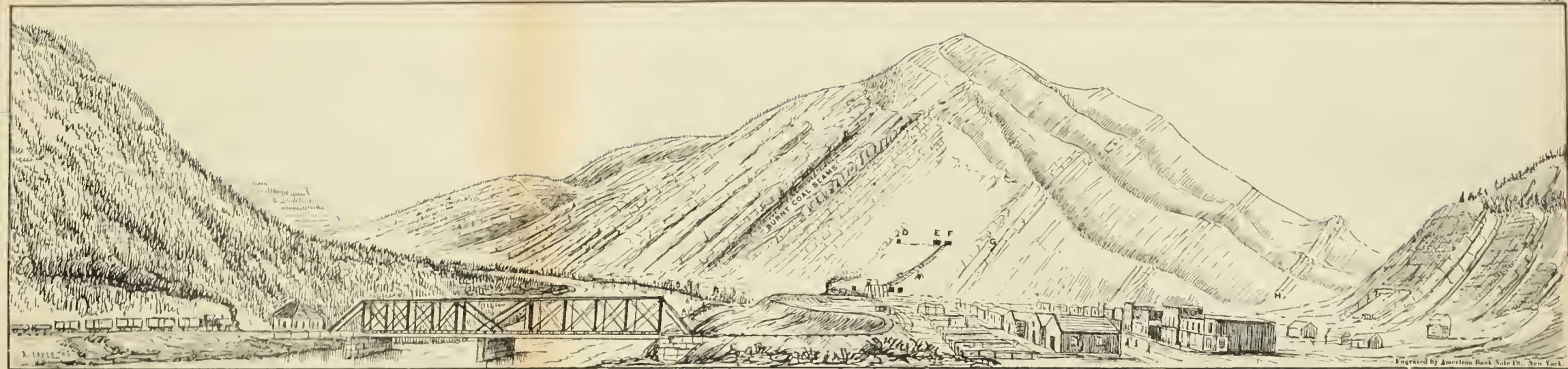
Could we from our standpoint follow the course of the coal hogback to the northeast, we should have to trace it for fifty miles curving around and gradually assuming a northerly route in the direction of Meeker and the White river plateau district, where there are extensive coal fields. It is cut through in that distance at intervals by different streams, such as Rifle and Elk creeks. In each of the gaps so formed the cross-section of the strata shows more or less coal beds of a workable size, so that for upwards of sixty miles along this hogback, coal may profitably be developed as railroads and markets make it desirable.

We ascended the hogback on its face with some difficulty, owing to its steepness and the presence of a foot of snow. We descended on the dip of the strata, following the depressions between the massive belts of sandstone, caused by the erosion of softer shales or coal seams, or indicating where a coal seam had been burnt out. On arriving at the base, we endeavored to obtain a cross-section of the strata overlying the principal coal seams, by following the course of the Grand river which cuts through the group at right angles. The strata consist generally of some 2,000 feet of drab yellow sandstone, very massive and heavily bedded. Some of these sandstones showed signs of fossil vegetation and cross bedding, and others of a concretionary tendency on a large scale. The shaly element in this portion of the group is in the minority. The dip appears to gradually diminish in steepness from 50 degrees at the coal seams down to 25 degrees near the upper portion of the group. The strata finally pass under the soil and drift of the valley of the Grand. Across the river about half a mile distant, horizontal table lands set in, which according



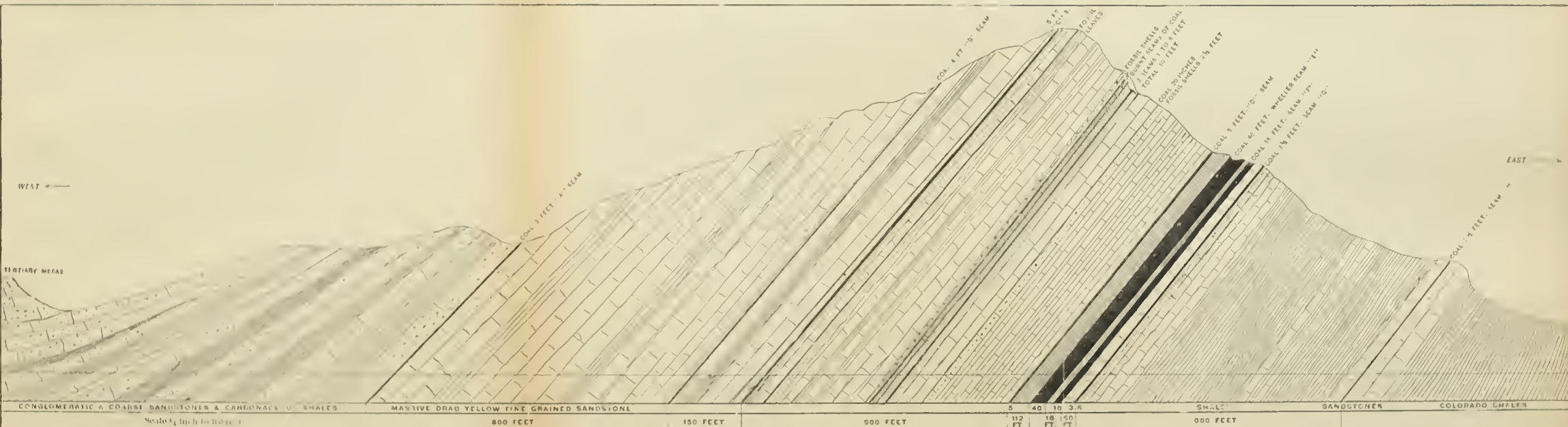






Engraved by American Bank Note Co., New York.

# COAL-RIDGE, NEWCASTLE, COLORADO.



## GEOLOGICAL SECTION OF COAL-RIDGE AT NEWCASTLE, COLO.

Engraved by American Bank Note Co., New York.



to Mr. Corryell, are formed of layers of conglomerate covered by basalt. No coal has been found in these table lands, which are doubtless of Tertiary origin. Mr. P. C. Corryell, the foreman of the Newcastle mines, who has a thorough scientific knowledge of the region, kindly gave me the following detailed section of the Laramie group at Newcastle, which will be intelligible by reference to the section on the plate.

SECTION OF THE LARAMIE COAL GROUP AT THE NEWCASTLE  
MINES, BY P. C. CORRYELL.

The "A" coal seam (three feet) is the uppermost seam of clean coal lying between ledges of massive coarse-grained sandstone. The sandstones lying above this seam are in regular ledges, alternating with clay shale, and a black Carbonaceous shale, which sometimes passes into a coaly substance. The sandstones near the upper series are more conglomeratic, and finally pass into a true conglomerate of pebbles, with some shale and marly sandstones, and a few fossil traces of molluscs. Below the "A" seam is a fine grained sandstone with small partings of coal and shale, until we reach the "B" seam, 800 feet below "A."

The "B" seam (four feet thick) is of very bright clean coal, the hanging wall is of heavy massive sandstone with a foot or so of shale immediately over the coal. The foot wall is of fireclay with a ledge of calcareous sandstone. Below this are several small coal seams, each a few inches thick, interstratified with sandstone and drab sandy shale, for a distance of fifty feet. Then follows a series of heavy bedded sandstones overlying the "C" seam. The distance between "B" and "C" is 150 feet.

The "C" seam (five feet thick) is of hard coal resembling the Sunshine seam. The hanging wall is shale fifteen inches thick, above which are eighteen inches of coal capped by the heavy sandstones. Below the seam is a footwall of shale and a bed of sandstone fifteen feet thick, followed by two feet of coal, and forty feet of carbonaceous shale with a number of small coal seams in it from an inch to twelve inches thick. These seams are followed by successive beds of sandstone and shale with a few small coal seams until we reach the line, where the coal has been burnt out, forming a little gulch about 300 feet wide.



Within this burnt area are three different coal seams respectively one, six and eight feet thick, with a belt of fossil shells forming the hanging wall of the lava seam. In places where the strata have not been much burnt the shells are so nearly perfect and in such abundance that the outcrop is a complete mass of them. These shells differ from the lower belt of shell in appearance and size. According to Dr. White of Washington, to whom I submitted them for examination, they appear to be fragments of *Ostrea Corbiculo*, *Anomia*, and *Goniobasis subloewis*, all Laramie types.

The strata between this little burnt out gulch and seam "D" (five feet thick) a distance of 350 feet, consists of heavy ledges of sandstone, with a few small seams of coal, and one belt of fossil shells about two feet six inches thick, between which and "D" seam laminated sandstones occur. The bed over "D," forming its roof, is a calcareous sandstone shown in fossil ripple marks and tracks of worms and worm borings between the partings.

The stratum between "D" seam and the Wheeler or "E" seam (forty-five feet thick) is a black carbonaceous shale. The parting of eighteen feet separating the Wheeler seam from the next seam "F" (sixteen feet) is a calcareous shale with iron pyrites and sand.

These formations might be divided into about four groups.

The great thickness of the Laramie group (3,000 feet), the massive sandstones it contains, and the number and magnitude of the coal seams amounting in all to over 100 feet of coal, are points in striking contrast with the development of the same group on the foothills east of the range, which rarely attains a thickness of 2,000 feet, with the shaly element predominating, and where the coal seams are rarely more than five or six in number. Even of these not over two and still more commonly but one is of workable size, averaging eight to ten feet. Here, however, we have two seams one sixteen the other forty-five feet thick, another of five feet close to it, and another of ten feet not far off, with a half a dozen others of workable size. It will appear then that the northwestern coal field is of far greater importance than the eastern. The coal also shows both by the analyses and



the practical uses to which it is put, that it is as a rule superior to that of the foothills. The regions around Trinidad and along the foothills have some advantage in facility of development because of the horizontal position of the coal beds in those regions, but the disadvantages of the steep pitch of forty to fifty degrees which characterizes the coals on this northwestern side are no greater than those of many of our coal mines on the eastern slope which have to be worked in highly inclined or nearly vertical seams. On the other hand, the advantages of nearness to markets and the accessibility of a great number of railroads tell at present in favor of those mines nearer the great plains. It is to be remembered, however, that the greater part of the States and Territories west of the Rocky Mountains will have to look to these northwestern fields for their coal.

Analysis of coal of the Newcastle mines, by Prof. George C. Tilden.

### GRAND RIVER COAL CO.

#### THE FIVE-FOOT-SIX SEAM ("D").

Water . . . . .	2.98 per cent.
Volatile matter . . . . .	42.25 "
Fixed Carbon . . . . .	50.09 "
Ash (light brown) . . . . .	4.68 "
	<hr/>
	100.00
Sulphur . . . . .	1.022

#### THE EIGHTEEN-FOOT SEAM ("F").

Water . . . . .	2.21 per cent.
Volatile matter . . . . .	39.10 "
Fixed carbon . . . . .	49.73 "
Ash (white) . . . . .	8.96 "
	<hr/>
	100.00
Sulphur . . . . .	0.832



## THE FORTY-FIVE-FOOT OR WHEELER SEAM ("E").

Water . . . . .	1.85	per cent.
Volatile matter . . . . .	41.58	"
Fixed carbon . . . . .	48.60	"
Ash (brownish white) . . . . .	7.97	"
	<hr/>	
	100.00	
Sulphur . . . . .	0.609	

## COAL RIDGE MINES. ELK MOUNTAIN FUEL COMPANY.

From Newcastle we retraced our steps two or three miles up the Grand river to the workings of the Elk Mountain Fuel Company. These consist of the aforementioned tunnel cutting through the top of the hogback about 1,000 feet above its base. From the river below water is forced by a steam engine through a pipe whose length is 5,200 feet, over 1,000 of which is up the steep slope of the ridge to the tunnel, through which it passes, and supplies water to the mines on the other side in Pinon basin, where the principal developments are being carried on. The extreme height of the Coal-Ridge hogback at this point is 1,800 feet, and the tunnel is located about 1,000 feet above the base. We ascended this by a zigzag trail, passing on our way over several important seams, some of them of great thickness, one being at least 22 feet thick, and when developed it may possibly prove to be 45 feet thick as at Newcastle, to whose Wheeler ("E") seam it appears to correspond. These seams lie between heavy beds of sandstone which occur at intervals of a few hundred feet with beds of shale or thin bedded sandstone between them. The tunnel is driven in about 325 feet below a notch in the crest of the hill from both directions, is 1,300 feet above the Grand river, and 7,000 feet above sea level. It is wide and capacious, eight feet high, seven feet wide at the roof and eight feet wide on the floor. The rock encountered in cutting it as shown in the accompanying section, was shale and sandstone, dipping about 45 degrees. A few fossil shells were found in the workings. At the time of our visit, there were a few hundred feet near the middle lacking for its completion; we have since heard that it was











finished on the 8th of May. It is 976 feet in length. The work, which was in charge of Mr. Ernest Locke, a former student of the State School of Mines, came together from both ends without the slightest variation. When the connection was made, a terrible wind swept through, blowing the workmen along and compelling the erection of banks at the south end to mitigate its force. Four seams of coal were met with in the tunnel which will be or are now being developed, under the superintendence of Mr. Blount.

Passing through the tunnel we emerge on the other side, and look down over the slope of the great hogback into Piñon basin. A few feet below the mouth of the tunnel are the boarding houses of the Company, and a trail leads off to the south along the back of the hogback toward Sulphur gulch, where two or more of the seams encountered in the tunnel outcrop on both sides. Openings have been made on these to connect with the main tunnel about 1,300 feet distant, by a gentle downward grade. There are other gulches adjacent to Sulphur gulch in which the same seams similarly outcrop, they could all be worked and united with the main tunnel by a tramway.

The two seams outcropping in Sulphur gulch about 200 feet apart, average five feet each in thickness, both carry a very superior quality of coal, one of them quite hard. The analyses will show their grade, and here it may be remarked that in this region quality is of far more importance than quantity. The local trade being small, this coal has to be shipped, and must command the market over other coals in order to pay; thus this company, under the advice of Mr. R. C. Hills, has gone into all this labor and expense of developing coal on the top of a very steep hogback, simply on the strength of finding some comparatively small seams of very superior quality, in preference to developing seams of enormous size but of inferior quality, much more accessible near the base of the hogback. These latter they keep in reserve for future years when more railroads and near markets will permit profitable working. But little timbering is necessary in these mines, as the walls are generally of firm or heavy bedded sandstone.



The capacity of these mines taken altogether would be about 5,000 tons daily, but at present they purpose to handle only 600 tons by their single tramway leading down from the tunnel. If the tracks were doubled they could handle 1,200 tons daily. They employ 150 men at present. The coal will be sent down by the tramway from the tunnel to the bottom of the ridge, and be received on a side track connected with the Midland railway, about a mile distant. The Denver & Rio Grande, whose tracks lie on the other side of the river, would also receive their coal. Their markets would be principally the states and territories on the western slope, while some of their superior coal will compete in markets nearer the Missouri river.

From the top of the ridge I took another panoramic sketch, (see plate XIII) which shows some country to the north that was obscured in the one taken from Newcastle. The geological section accompanying it, was taken up one of the tributaries of Elk creek a little north of Newcastle, and shows the geological relations of the strata in the vicinity from the Archæan granite mountains on the east to the Tertiary plateau on the west.

#### ANALYSIS OF COAL OF COAL RIDGE (ELK MOUNTAIN FUEL CO.)

[ By Professor Tilden ]

##### SULPHUR GULCH MINE.

Water . . . . .	5.29 per cent.
Volatile matter . . . . .	40.70 "
Fixed carbon . . . . .	49.73 "
Ash (light brown) . . . . .	4.28 "
	<hr/>
	100.00
Sulphur . . . . .	546

##### SEAM NOT CUT BY MAIN TUNNEL AT TIME OF VISIT.

Water . . . . .	5.14 per cent.
Volatile . . . . .	40.14 "
Fixed carbon . . . . .	51.46 "
Ash (red) . . . . .	3.26 "
	<hr/>
	100.00
Sulphur . . . . .	0.580



## SUNSHINE DISTRICT, JEROME PARK.

We returned to Glenwood, and next day in company with Mr. Morgan, superintendent of the Grand River Coal Mines, went by sleigh to Cardiff, five miles south of Glenwood, up the Roaring Fork. This is the central outlet and point of delivery for the mines of Sunshine, Marion and Spring-gulch belonging to the Grand River Coal and Coke Company, it is also the coking place for the coals from those mines. A long line of coke ovens has been built, a hundred of which are in active use and another hundred in course of completion. The ovens are built of red sandstone and are of the rectangular arch pattern producing both 24 and 48 hour coke. A very large tippie receives the coal from the mine and dumps it into the coke larries which run along on top of the ovens. The demand for the coke is in excess of the supply at present, it is taken principally by the silver smelting works along the eastern foothills and in the states and territories west of the range.

The valley of the Roaring-Fork at Cardiff is cut out of a sharp anticlinal arch in the red beds. The red rocks on the east side of the valley dip a few degrees to the east, and on the opposite side they are vertical, gradually dipping at a steep angle to the west. As the Silurian and Paleozoic series to the east again dip west off from the Sawatch range, a synclinal along Frying-pan creek must occur between Roaring-Fork and the Sawatch range, followed by an anticlinal. This is but the beginning of the disturbances caused by the uplift of the Elk mountains which we find so powerfully developed as we approach them. The general effect is to crumple up the strata between them and the Sawatch range.

From Cardiff the coal train by a branch line cuts through all the sedimentary beds across their dip and shows a good section from the Trias to the Laramie.

First we pass through a great thickness of Triassic "red-beds" standing vertically and among them traces of eruptive action and remains of basaltic overflows of very vesicular lava which must have poured out on the surface. Boulders of this lava we find widely strewn over the whole area, and sometimes completely



covering the surface of the hills and valleys, especially the Fox-hill shales, and portions of the Laramie group.

Next comes a little valley of soft variegated Jurassic strata followed by the Dakota sandstone ridge dipping fifty degrees west. In this sandstone ridge a belt three feet thick of blue fireclay is found as at Golden, which has been successfully used for lining the coke ovens at Cardiff.

Next to the Dakota hogback is another flat valley occupied by the soft shales of the Fox-hills and Colorado cretaceous.

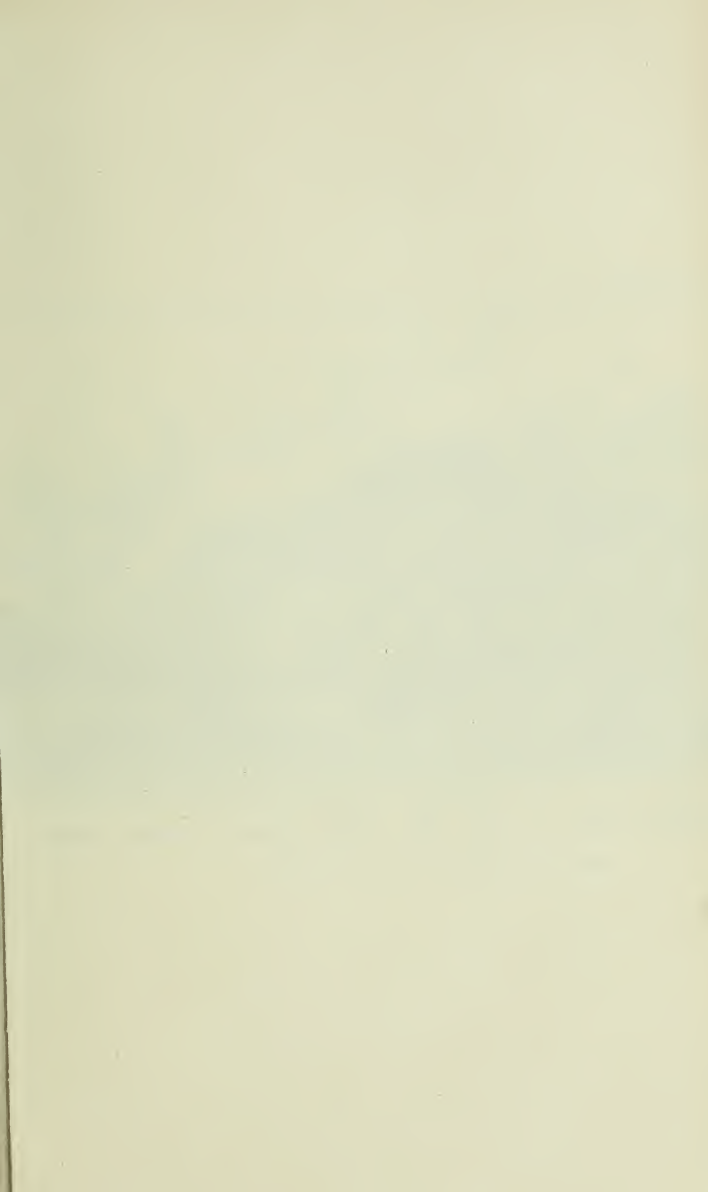
Then we come to the lofty hogback of the Laramie coal series dipping forty-five to fifty west. We pass up Sunshine gulch through a section of this, which shows its thickness to be several thousand feet. The bluffs rise 2,000 feet above the valley, the strata are similar to those at Newcastle, but on one side of the creek are obscured by volcanic matter.

These mines have been in operation about fifteen months. The development is principally upon one seam about ten feet thick towards the middle of the series. The coal is hard and has a semi-anthracitic appearance, and is much prized in the neighborhood, especially for domestic purposes. The development consists of a tunnel, driven in on the strike of the coal from just above the level of the creek for 1,500 feet; from this three incline slopes about 150 feet deep and on a dip of 45 degrees, descend to a lower tunnel, driven in the same way for 1,100 feet. The floor and roof on either side the seam are of heavy bedded sandstone. The lower tunnel being below the bed and level of the creek is wet, and pumps are necessary. Two double boiler engines for hauling up the laden cars by tail rope from the slopes were in process of erection. The coal is discharged over a tippie into the cars of the Midland railway, whose branch line runs along the bottom of the gulch. From the lower level the mines can stope upwards for over 1,000 feet, and for an unknown distance north and south.

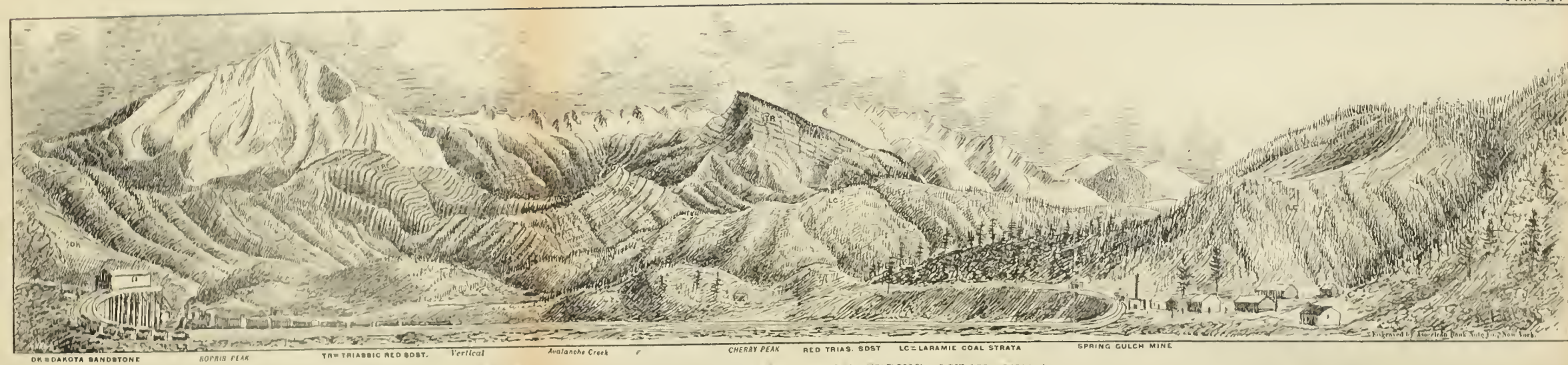
Besides this ten feet Sunshine seam, three other workable seams outcrop on this property in a lower series 800 to 1,000 feet below the upper seam. On these no developments of importance have been made.

The roof of one of these seams consists of a bed two to three feet thick of fossil shells, so abundant and so compressed together









VIEW OF SOPRIS PEAK & ELK MTS. FROM SPRING-GULCH MINES.

GRAND RIVER COAL & COKE CO'S MINES.



that the rock may be called a shell-limestone. According to Dr. White they are species of *Ostrea*, *Corbicula* and *Unio*. Above this shell bed are the ordinary drab yellow sandstones, below it are about five feet of lignitic shale capping a coal seam four feet thick, separated from a still lower coal seam five feet thick, by about twenty feet of thin bedded sandstone. Below these coal seams are some 800 feet of sandstones and shales, before we reach the true marine Cretaceous shales of the Fox-hills group. In the sandstone between the two seams we found an impression of *Halymenites*, and also part of a palm or a reed with a *Carpolithes* or stone fruit. This shell-bed represents a lake or body of water fringed by vegetation, but probably not far above the sea level, as implied by the *Halymenites*. The shells are of fresh or brackish water origin, and true Laramie types. This fossil-bed is traceable to Marion gulch six miles south, where it also forms the roof of one of their coking coal seams, and upwards of thirty miles to the north we found fragments of the same shells at the foot of Coal Ridge, and further on about four miles we have already described the shell-beds of the Newcastle mines. The lake or body of water must have had a length of at least thirty or forty miles so far as present discoveries show, and probably a very much greater extent.

#### MARION MINE.

From Sunshine we took the afternoon coal train to Marion. We wound around several headlands of the Laramie bluffs and found ourselves suddenly on the rim of Jerome Park basin, lying far below us. From the edge of the basin we have a magnificent view of Sopris peak, and looking up the deep gorge of Crystal river and Avalanche creek (see plate XV) we observe that the Dakota together with the "Red-beds" and other Mesozoic strata curve around the peak, like the circling walls of an amphitheater, with the volcanic dome in the center. The dip also becomes very steep and often vertical, as if the strata had been thrown back on all sides, as the monstrous "laccolite" arose intrusively among them.

It was sunset when we reached the mines, but before darkness



came on we visited a recently opened seam of hard coal, up the Marion gulch. This seam is supposed to correspond to the Sunshine seam. Owing to local faulting and pinching, it showed at first only a few inches on the surface, but at 100 feet opened up to between four and five feet in thickness. This seam is a thousand feet above the lower seams worked at Marion, and as the latter correspond to a lower series of seams at Sunshine, as shown by the fossil shells forming the roof, it is probable that this new-found seam corresponds, as is supposed, to the upper Sunshine seam.

They are working three seams of coal, one six feet thick of coking coal; another, forty-five inches thick, which is overlaid by the fossil shell-bed, and separated from the next, which is four feet six inches thick, by sixty feet of sandstone and shale. Fifty feet of sandstone and shale is again followed by another seam ten feet thick. A seam of "bone" two feet thick, gradually diminishing in size, comes in near the foot wall and above the last foot of coal, to avoid which they work only eight feet of coal.

The developments at Marion are three tunnels, the upper one 1,500 feet, the two lower 4,000 feet each. The coal is discharged from the upper workings by a gravity incline tramway, with an automatic arrangement at one end of the car for uncoupling it, thence over the tippie to the railway cars below. The present workings are fifteen months old, but the mine had previously been worked in a small way to get coke for the Aspen smelters, and a small plant of a dozen ovens still remains on the ground. This plant is now being increased to 100 ovens.

The output of this mine is 250 to 300 tons daily, the greater portion of which is turned into coke.

#### SPRING GULCH MINE.

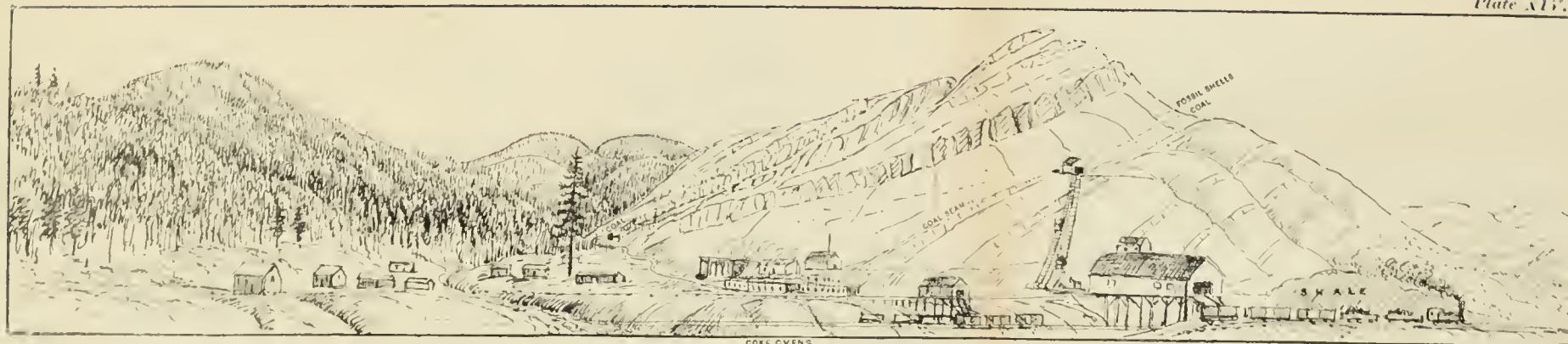
From Marion we walked to Spring Gulch. This is, in many respects, a counterpart of Marion. Three seams occur here named respectively "A," "B" and "C;" "A" is ten feet, "B" is six feet and "C" four feet thick. "A" is the lowest, "B" is forty-eight feet above it, and "C" fifty feet above "B."

The workings on the south side of the gulch are two. The









COKE OVENS  
**MARION COAL MINE**  
GRAND RIVER COAL & COKE CO'S MINES



## SUNSHINE COAL MINE.

### SECTION OF COAL STRATA AT SUNSHINE



tunnel entry on "A" is 600 feet long; on "B" 2,500; on "C," with three air courses to the surface, 1,200. There are four air courses on "B" to the surface and one in "A." The length of one slope incline is 230 feet. The air course goes from "A" to the surface entry.

On the north side the "A" seam is not worked. On "B" there is a tunnel 1,350 feet, and on "C" 1,200 feet. There are three air courses to the surface on "B." The distance of upstopping to surface is 75 to 150 feet, according to the slope of the mountain. The lower rooms are 150 feet with a thirty-foot square butt, and eighteen-foot pillar between each room. Rooms are 20 feet wide and 150 feet long. A steam engine is employed, (double reversible), of 175 horse power, double boiler. The roof is good. They are working eight feet of "A," four feet of "C" and six feet of "D," and are mining coal for about seventy-five cents per ton. The daily output is 250 tons, which could be raised to 500 tons, lump and slack. It is from Sunshine and Marion that the company derives the most of its coke.

Analyses of the coal of the Marion, Sunshine, and Spring Gulch mines, Grand River Coal and Coke Company, by Professor George C. Tilden.

## MARION, SIX FEET SEAM.

Water . . . . .	2.07 per cent.
Volatile matter . . . . .	39.67 "
Fixed carbon . . . . .	55.19 "
Ash (light brown) . . . . .	3.07 "
	<hr/>
	100.00 "
Sulphur . . . . .	0.916 "

## MARION NO. 2.

Water . . . . .	2.17 per cent.
Volatile matter . . . . .	39.51 "
Fixed carbon . . . . .	51.72 "
Ash (red) . . . . .	6.60 "
	<hr/>
	100.00 "
Sulphur . . . . .	0.602 "



## MARION NO. 3.

Water .....	2.30	per cent.
Volatile matter.....	35.67	"
Fixed carbon .....	56.71	"
Ash (brown).....	5.32	"
	<hr/>	
	100.00	"
Sulphur.....	1.521	"

## SUNSHINE, SOUTH SIDE, LOWER GANGWAY.

Water.....	3.40	per cent.
Volatile matter.....	40.32	"
Fixed carbon.....	48.82	"
Ash (light brown).....	7.46	"
	<hr/>	
	100.00	

## SPRING GULCH, FOUR-FOOT SEAM.

Water.....	1.26	per cent.
Volatile matter.....	36.95	"
Fixed Carbon.....	54.89	"
Ash (brown).....	6.90	"
	<hr/>	
	100.00	
Sulphur .....	1.216	per cent.

## SPRING GULCH, NO. 2.

Water.....	1.77	per cent.
Volatile matter.....	34.63	"
Fixed carbon.....	57.24	"
Ash (brown).....	6.36	"
	<hr/>	
	100.00	
Sulphur .....	1.018	per cent.



## THE ROCK CREEK AND COAL BASIN DISTRICT.

From the Sunshine and Jerome Park district we had intended working one way along the course of Rock Creek in the direction of Gothic and Crested Butte up Coal creek and Yule creek to coal basin and the marble beds through one of the most interesting regions in Colorado, but were unable to carry out our plan owing to the deep snow. It is in this direction that the great dynamical forces of the Elk mountains show themselves most violently. Along Rock creek occur most remarkable folds, reversals of strata, and great faults, while the action of the heat of the eruptive masses and that mechanically produced by overturning is manifest in the general metamorphism of the strata. The coal is frequently turned into anthracite and the limestone into a beautiful white and blue marble. In the centre of the axis of the folds the great eruptive laccolites rear their massive grey domes and roll back the thick sedimentary strata from them "as we roll back the coverlet from a pillow." As important coal beds lie in this section, we quote Prof. J. S. Newberry's account of them.

## THE COALS OF COAL BASIN.

BY PROF. J. S. NEWBERRY, OF COLUMBIA SCHOOL OF MINES, N. Y.

About 40 miles north of Crested Butte and as far south of Glenwood Springs, is a district which has been called Coal Basin. This is one of the most peculiar and interesting areas which I examined in Western Colorado.

It is evident that the Laramie coal measures, which before were nearly all horizontal, were once at this point raised into a dome by the protusion of a mass of eruptive rocks. The central portion of the dome—doubtless considerably broken up—has since been removed by erosion to form a basin five miles long by three miles wide. The center of the basin is excavated deeply into the Colorado shales, the middle member of the cretaceous system of this region, while its rim is formed by the Laramie group 2,000 to 3,000 feet in thickness, which dip away from the center in every direction.



In the cliffs which border the basin the coal seams are exposed and accessible in many places ; the number and thickness of these seams vary considerably, owing to local changes, and to the different degrees to which the margin has been eroded. Where most numerous and distinct there are five or six workable seams, viz., three above the lower sandstone ; one, sometimes two or three, above the middle sandstone, with one in the upper sandstone, and several small seams above. At the west end of the basin the lower three seams are closely approximated and in one place run together, forming what may be regarded as a single seam about eighteen feet in thickness. Generally the three seams are separated by a few feet of sandstone.

The eastern rim of the basin is formed by rocks older than the Laramie, viz: the Colorado shales and Dakota sandstones, and below these the Jurassic and Triassic strata, which form the walls of the very picturesque cañon of Coal creek, the outlet of the basin. These walls are 2,000 feet in height, composed chiefly of purple sandstones weathered into all sorts of fantastic and imitative shapes. Rising abruptly from the green bottom lands of Crystal river, they form one of the most striking and beautiful portals I have ever seen. These older rocks are here thrown up by a fault or sharp fold, which crosses Crystal river obliquely above the mouth of Coal creek. South of this line the Laramie rocks come down and form for many miles the walls of the valley of Crystal river, but apparently contain no very good or accessible coal. Chair Mountain on the west side of the valley contains some anthracite, but it is too much broken up to be of any value.

#### MARBLE BEDS.

Twelve miles south of Coal Basin, Yule creek joins Crystal river from the southwest. For several miles the valley of this stream is excavated in Palæozoic limestones, in which is the finest belt of marble yet discovered in the United States. The beds stand nearly verticle, are about 150 feet in thickness, and of this nearly one-half is pure white, and would be classed as statuary marble. Toward the top of the deposit are some layers of the purest, loveliest blue marble ever seen.



The coals of Coal Basin are all of the same general character, though differing considerably among themselves in the degree to which this character is developed; that is, they apparently all belong to the class of coking coals, and are generally of good quality, containing a small amount of ash and sulphur.

At the eastern end of Coal Basin the lowest coal seam lies high up in the hills, and is widely separated from its fellows. It is seven feet in thickness, looks well, but is peculiar in composition and inferior in quality to any other coal observed in the basin, since it contains ten per cent. of ash and 0.142 of phosphorus. Toward the west end of the basin all the coal seams come down, and the entire section of the Laramie rocks is represented in the cliff nearly 3,000 feet in height. At its base the lowest three seams are united in one, or closely approximated, giving eighteen feet of coal in three benches or distinct seams. They are very much alike in appearance and quality, containing about one per cent. of sulphur, and 0.011 of phosphorus. A higher seam, from seven to eight feet in thickness, is of similar character and purity. These coals make excellent coke, and as they underlie an area of many thousand acres, are capable of furnishing an inexhaustible supply of fuel for the future iron and lead smelting of Colorado.

The coal properties on the south and west sides of Coal Basin belong to the Colorado Fuel Company, of which Mr. T. C. Osgood is president; those on the north side of the basin have been acquired by the Midland Railroad Company.

To connect the coal mines of this district with the markets, a railroad is being constructed down the valley of Crystal river to Carbondale, where it will join the D. & R. G. and Midland roads.

#### ANALYSES OF COAL OF COAL BASIN.

By Prof. J. S. Newberry and R. C. Hills.

##### COAL BASIN, CLAIM E.

Moisture .....	1.089 per cent.
Volatile.....	36.674 "
Fixed carbon.....	52.956 "
Ash.....	8.981 "
Sulphur.....	0.834 "
Phosphorus.....	0.03859 "



## COAL BASIN, CLAIM H.

Moisture.....	0.686 per cent.
Volatile Matter .....	32.682 "
Fixed carbon.....	56.036 "
Ash.....	10.140 "
Sulphur .....	0.454 "
Phosphorus .....	0.142 "

## COAL BASIN, 20 FOOT SEAM, OUTCROP.

Moisture.....	0.615 per cent.
Volatile matter.....	23.532 "
Fixed carbon.....	67.030 "
Ash.....	7.993 "
Sulphur .....	0.558 "
Phosphorus .....	0.011 "

## COAL BASIN, 20 FOOT SEAM, UPPER BENCH.

(R. C. Hills.)

Moisture.....	1.9 per cent.
Volatile matter.....	23.4 "
Fixed carbon .....	71.1 "
Ash.....	3.6 "

## COAL BASIN, 20 FOOT SEAM, MIDDLE BENCH.

(R. C. Hills.)

Moisture.....	1.1 per cent.
Volatile matter.....	22.1 "
Fixed carbon .....	72.3 "
Ash.....	4.5 "

## COAL BASIN, 20 FOOT SEAM, LOWER BENCH.

[R. C. Hills.]

Moisture.....	1.9 per cent.
Volatile matter.....	20.6 "
Fixed carbon.....	73.0 "
Ash.....	4.5 "



## CHAPTER IX.

# Coal Fields of the Crested Butte Region.







## Chapter IX.

### COAL FIELDS OF THE CRESTED BUTTE REGION, GUNNISON COUNTY.\*

These coal fields lie in the heart of the Elk Mountains. To reach them from the "Plains," we cross three parallel ranges, the Colorado or Front range, the Park range, and the Sawatch range, separated from one another by trough-like valleys and parks. On the northwest of the Sawatch range, separated from it by parks and valleys of sedimentary rocks we encounter a unique group of plateaus, domes and lofty pyramids of eruptive rock, coming up through and tossing back the sedimentary beds like sheets of cloth or paper. These are the Elk mountains. Within a comparatively small area in this region, are to be found the most striking examples of volcanic outbursts, dykes, and intrusive beds of eruptive rock, accompanied by overturnings and even reversals of sedimentary rocks, with wonderful folds and faults, and more or less baking and metamorphism of the surrounding strata.

We find the same general geological section as on the eastern plain border, reproduced with slight modifications on this western side also; and though the strata are riddled with dykes baked and metamorphosed in places almost past recognition, we easily detect the same plant fossils and marine shells which we have met in similar relations to the coal on the plains.

Though the coal is in part anthracite, a form of coal popularly associated only with the true Carboniferous coal regions of Pennsylvania, yet by the fossils associated with it we recognize it as the same so-called "lignite" coal of the plains and foot-hills,

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\* The description of this coal field is drawn from my report of 1885, with some corrections and additions. The developments in the field have not materially changed any points noted in that report, except in the matter of output, which has largely increased.



metamorphosed or changed by heat into anthracite. It is in the same geological horizon, the Upper Cretaceous, and both on the roof of the Anthracite mine and the coking coal mine of Crested Butte we find the same familiar Upper Cretaceous palm and plant leaves, while in the sandstone at the base are the seaweeds (*Haly-menites*) of the "fucoidal sandstone," and below that again in shales, burnt into hard black slates, are the shells (*Inoceramus problematicus*) of the marine Cretaceous. The change is not in the geological relations of the coal, but in the physical character of the coal itself.

That the coal should be in the same geological horizon as that on the Eastern plains is not surprising, if we consider that the front range and the Sawatch were at one time parallel reefs in an almost universal ocean. The same sea beat against the Eastern and Western border, depositing marine strata of a similar nature on both sides. The ranges were elevated gradually, admitting of a land and fresh water area on both slopes, favorable to the growth of coal vegetation. The energies which gave greater elevation to these ranges found relief on the western flank of the Sawatch, in violent outbursts of molten matter, which welling up from regions below, tossed the overlying sedimentary beds like waves in a storm, penetrating them by long fissures and giving birth to huge bodies of lava united to one another by dykes; from these also, between the strata, wedge-like sheets of lava were intruded. The heat thus engendered and continuing long after all active eruption had ceased, permeated the surrounding strata, producing more or less general metamorphism according to the nearness or distance from the volcanic source; shales and clays were hardened or changed into slate, sandstone into quartzite, limestone into white marble; brown lignite, into semi-bituminous, semi-bituminous into bituminous, that into coking coal, and that into semi-anthracite and anthracite, and we may yet find in the region the last degree of metamorphism of coal, namely graphite or black lead. The remaining features are the result of erosion. After the general uplift and volcanic disturbance, which was at least after the Cretaceous, the region seems still to have been a point of volcanic ~~un~~quietness, for we find newer dykes penetrating the older masses



of lava, and even, I am told by Mr. Whitman Cross, of the United States Geological Survey, remarkably recent looking basalt overflows the glacial drift, which brings the date of volcanic eruptions, as at Glenwood, perhaps up to the human period. Faults are also observable, some probably contemporaneous with the eruptions, but others traversing eruptive sheets and sedimentary strata alike, so that after the eruptive forces subsided, regional contraction of the strata disturbed and faulted them as at Leadville.

In a region so disturbed and so influenced by heat we should expect precious mineral veins, and such we find, usually as fissure veins at contact between volcanic and sedimentary rocks, or in one or the other formation only. The gangue, usually quartz or a "breccia" of quartz and slate, carries a variety of minerals, principally iron, copper and arsenical pyrites with much brittle and native silver, in wire-like bunches, in pockets, or in surface float, also ruby silver. Galena is less common than usual and is generally fine grained and rich in silver.

Gray copper also occurs, running 100 to 200 ounces in silver.

The coke and coal are at hand ready to smelt these ores and save cost of shipping.

Descending the Sawatch range by the Marshall Pass we find ourselves in a plateau region extending far to the southwest and west, where the distance is closed by the volcanic San Juan Mountains; the intervening country is covered with lava, resting either directly on granite or capping horizontal Cretaceous beds. The great local development of the Cretaceous accounts for the presence of the large coal fields of the region. To the northeast appear the cones, pyramids and castles of the Elk Mountains. Through this country flows the Gunnison River, heading by many small tributaries in the Elk Mountains and flowing South in a wide, clear stream, emptying into the Grand River. On a broad flat on its south bank lies Gunnison City. On the opposite bank are some picturesque cliffs of volcanic breccia upwards of 1,000 feet thick resting upon conglomerates and sandstones of Cretaceous age, as indicated by fossil plants. This "breccia" covers the surface and fills up ancient ravines cut in the sandstone, showing that the surface of the country had been eroded into hill



and valley before the volcanic flood of lava deluged it, overwhelming the hills, filling up the ravines and reducing the surface to a level, now cut up by erosion into table lands or "mesas." The materials composing this "breccia" are angular blocks of grey lava from the size of an egg to a ton in weight, cemented together by a paste of volcanic sand. A stratified structure is visible as if the "ejecta" had been deposited under the influence of water; the dip is about  $20^{\circ}$ . The "breccia" is weathered into phantastic forms, "hoodoos," pinnacles, columns often with a large block of lava capping a monument. This "breccia" together with some beds of sandstone form the banks as we ascend the river for some miles, then granite appears in the cañon of an offshoot of the Sawatch. Upon this, Cretaceous sandstone rests directly and horizontally, a geological feature different from that on the plains, where the lower rocks, such as the Trias, Carboniferous or Silurian usually occupy that position.\* In places the granite is either bare or capped with "breccia." This Cretaceous sandstone, about 500 feet thick, is our first introduction to the coal measures.

The tributaries of the Gunnison come in as we ascend the stream, first Ohio Creek from the North, heading up near the anthracite basin of Irwin, with coal beds along its course. East River soon joins the main stream with Taylor River, and lastly Slate River comes into East River. As we ascend Slate River the first grand group of the Elk Mountains comes in sight. Domes or pyramids of ashen-gray or whitish lava carved into pinnacles and spires by melting snows, rise, bare and bleached, above a dark skirting of pine trees; such are Crested Butte Mountain, 11,830 feet above the sea, and Gothic Mountain, twin mountains, though some miles from each other. Others present a more castellated or table form, such as Teocalli Mountain where tiers of horizontal red strata seem lifted bodily up on a volcanic dome. Other great grey massive domes of lava are deeply sculptured by broad amphitheaters at their crests, suggesting craters, but in reality the seats of by-gone glaciers; such are Wheatstone Moun-

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\* The inference is, that this portion of Colorado was above the sea during the whole of the Paleozoic and Part of the Mesozoic eras, and was not submerged until the Cretaceous epoch.





Baker Creek

MI WHEATSTONE

C.C. BIGGONS OVERS

Tunnel

Town of Crested Butte

Slate River

EMMONS Pt.

Obejoyful Creek

Poverty Gulch

Augusta Mine

Anthracite Mesa

GOTHIC MT

WHITE ROCK MT

THE CRESTED BUTTE

PANORAMA OF THE CRESTED BUTTE COAL REGION.

The broken line indicates the Coal horizon







tain and others. We halt at the thriving little town of Crested Butte on the bank of Slate River and about one mile west of the peak which gives it its name. The town is located close to the coal mines and coke ovens of the C. C. & I. Co.

The illustration, reduced by Prof. P. H. van Diest from a sketch of the writer's, will give an idea of the scenery looking up the river, and the line and area of the workable coal.

To the right and east is Crested Butte Mountain, an eruptive mass of quartz porphyry, with horizontal Cretaceous shales at its base. Beyond it is the road going over to East River and Gothic Mountain, the latter being in a direct northeast and southwest line with Crested Butte Mountain, and connected with it by either a dyke or an overflow. Opposite Gothic, Copper Creek runs up to Whiterock Mountain, one of the centers of eruption. Its huge dome of ashen grey eruptive diorite is thrust up through the sedimentary strata. Opposite Whiterock Mountain is the Sylvanite Mountain and mine, particularly rich in wire and native silver, in a fissure vein. There is a whole group of mines here located on fissure veins in eruptive rock, having a general northwest and southeast direction. Continuing up East River to the northeast of our sketch is Baldy Mountain, a near relation of Gothic Mountain and Bellevue, leading on to the Snow Mass group, in the direction of Rock Creek. This is another eruptive "focus." Between the Whiterock and Snow Mass as centers of disturbance the strata are folded back, reversed and faulted along a line of fracture. Dykes and igneous sheets occur, and a general metamorphism has taken place; hence we have on Rock Creek coal changed to anthracite, limestone into some of the finest white marble we have ever seen in America, and said to exist over a considerable area and thickness. Anthracite and natural coke also occur where a dyke of lava has intruded into the coal strata. These important deposits await only a railway to make them accessible to market. The marble is likely to be of particular importance in the west. All these phenomena are heat products incident to the eruptive forces, and possibly also to the mechanical heat produced by the friction of violently folded rocks in the course of mountain making.

At the top of the picture, northwest, Augusta Mountain,



with the Augusta mine at its summit, and Cascade Mountain stand between the forks of Poverty Gulch and Slate River. This is another mining area. Pittsburg village lies at the foot. From this point, looking down Slate river, the coal strata are seen forming a narrow, steep, flat-topped bench, on either side of the river, rising toward the north, and dipping to the southwest, as we go down stream, until at Crested Butte the coal reaches the level of the river and again ascends gently towards the south in the direction of Wheatstone. About half way on the west side "O Be Joyful" Creek and gulch cut through it, and opposite, on the east bank, is the Anthracite Mesa, with the anthracite mine of the Colorado Fuel Company, 1,000 feet above the level of the river. The same anthracite ridge is traceable, on a descending scale, to Crested Butte Mountain on the east side, while on the west, at a higher level, it flanks Mount Emmons, and is cut at Crested Butte City by Coal Creek on the west, which leads up to the Irwin anthracite basin, twenty miles distant, and is continued from Coal Creek to Baxter Creek by the ridge of the Colorado Coal and Iron Company's coking coal mines, gradually passing out along the base of Mount Wheatstone, where the coal is poor and is said not to coke. The valley of Slate Creek is from a mile to one half a mile wide, rising toward the north. It divides the coal plateau in two, and the stream flows through the trough of a synclinal fold.

It appears then that the coal area here consists of a narrow strip of gently dipping strata about fifteen miles long by two miles wide, sawed out in the center by Slate River Valley half a mile or more wide, walled in by volcanic dykes and eruptive mountains on both sides, east and west and to the north, tipped up by these on each side as it approaches them. On the east, Crested Butte and Gothic Mountain, with their dykes limit it. Mount Wheatstone and a twin volcanic mountain connected probably by dykes with Mount Emmons limit it on the west. The elevating forces seem to have been greatest towards the northwest, where prodigious and numberless dykes give evidence of great volcanic energy. Thus the strip of coal strata was encircled by mountains of heated lava as by the hot walls of an oven, metamorphosing it in a gradual gradation, from



bituminous and coking coal to semi-anthracite, and finally to anthracite; the metamorphism increasing as we go up the gulch to the center of elevation, volcanic disturbance and heat. The coal field is a small one, for when not restricted merely by erosion (as in the case of the anthracite mesa) it will be limited when the abutting strata cease against the volcanic walls. It is a fragment of the greater coal field of the country, isolated by up-thrusts of volcanic lava from other portions of the basin, such as the anthracite basins at Irwin and Rock Creek, whose geological position is the same, viz: Upper Cretaceous.

With regard to these great volcanic masses, some are undoubtedly huge dykes coming up from below and eroded into individual peaks. These would cut off the coal as by a wall. Others again are intrusive sheets of lava issuing from a parent dyke and wedged in between the strata. Others may be "laccolites" or bodies of lava coming up from below, but which not having had force enough to reach the surface, arched up the overlying strata, forming a great oven shaped cavity filled with solid lava. Remove the surface rocks from this by erosion, and dome-like mountain masses of lava, such as Gothic or Crested Butte would result. Wheatstone and similar peaks may have the same origin, they have not much disturbed the strata, but have gently elevated and altered it by their heat.

The short distances within which the changes in the character of the coal occur are worthy of notice.

At the base of Wheatstone Mountain the coal is said to be bituminous, and not coking. Two miles up stream, at the Colorado Coal and Iron Company's mines, it is coking and charged with inflammable gases; one mile further north it becomes semi-anthracite at the Warner mine; two miles further it is genuine anthracite at the Anthracite Mesa, and continues anthracite to the head of the creek. Within a distance of six miles all these changes take place. It will appear then that limited as is the coal field, the different kinds of coal are still more restricted. coking coal will be limited on the west by the volcanic wall stretching from Wheatstone to Coal Creek, and about three to five miles back of the Colorado Coal and Iron Company's coal hill it will probably become more anthracitic and less coking, as



it approaches these volcanic limits. There is area, however, enough for many years to come. Less than a mile north of it the semi-anthracite area comes in, followed by the true anthracite, limited in the same way by the Gothic and Crested Butte dyke on the east, as well as by the erosion of Washington Gulch; by a faulted area on the north, and on the west side by the dykes of Mount Emmons and "O Be Joyful" Creek, and to the north by the dykes of Augusta Mountain and Poverty Gulch.

I have traced the anthracite coal to the head of Poverty Gulch. It is there upwards of 2,000 feet above the valley, and would be difficult of development. A narrow strip of different varieties of coal extends from one end of the valley to the other, interrupted by gulches, dykes and faults for a distance of about fifteen miles, but unitedly not averaging more than one mile in width and two and one-half or three miles in greatest width.

THE COLORADO COAL, COKE & IRON CO.'S MINE AT CRESTED  
BUTTE.

The "mesa" or hill in which this mine lies, is about two miles long by three miles wide, from Baxter Creek on the south to Coal Creek north, limited on the west by the Volcanic Mountains, and east by the Slate River Valley. This probably represents the utmost limits of the coking coal area. At Crested Butte the coal touches water level, the old workings being below water level; thence it seems to rise gently towards Mt. Wheatstone. The hill is of sandstones and shales unaltered by heat, the lower portion is shale; the hill is about 600 to 800 feet high. On Baxter Creek, in a block fallen from a bed of yellow sandstone from near the top of the hill and in close proximity to the coal, I found small pectinated shells associated with stems of trees that may prove of interest in the contest of geologists as to whether the coal is upper Cretaceous or lower Tertiary. Above this sandstone I found a coal seam, apparently three to four feet thick, and another about half way up the hill, above Baxter's house, also about five feet, (No. 1 of analyses) and not coking. Miners claim there are five seams in the hill, beginning from the base with intervals of shale and sandstone.



1	Seam . . . . .	10	feet, not cokable.
2	" . . . . .	6	" } cokable.
3	" . . . . .	5	" }
4	" . . . . .	4	" not cokable.
5	" . . . . .	2	"
		<hr/>	
		27 feet.	

The non-cokable seams might prove coking if worked below water level. The coal seam six feet thick is worked close to town; the new opening is on a bench 100 feet above the river level. The old workings and the most extensive were sunk by drift and tunnel below the water level, but since the fire-damp accident, owing to the prevalence of faults and other reasons, they have been abandoned and are now full of water. The general dip of the coal is to the west, rising, however, as it approaches the mountains. The new entrance tunnel is twenty feet wide by six feet high for some distance, contracting to ten feet within the main entry. Side entries diverge from this at an angle of  $45^\circ$  and are run diagonally across the dip, which reduces its steepness from  $8^\circ$  to  $4^\circ$  or  $5^\circ$ , quite sufficient for the down grade of the laden cars to the main entry.\* The latter is also so driven along the seam and dip and to the raise as to afford a gentle down grade of two feet in 100 to haul the laden cars to the pit's mouth, whence they run down an incline plane on rollers and wire ropes worked by steam to the shutes and are discharged into the cars close to the coke ovens.

The coal seam is free from slate, is soft and easily mined with pick alone, no powder being used in the mine since the fire-damp accident. Two men can turn out about nine tons daily. The roof is poor, being composed of shale about two feet thick, overlaid by treacherous sandstone. Masses of this shale slack off and fall from time to time, involving the necessity of timbering. Accidents in mines from bad roofs are the commonest in Colorado, as testified by the inspector's report. A ticking sound is heard constantly from the escape of gases in the coal. The ventilation at present seems ample. A ventilating furnace is built

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\* The greatest distance from the entrance is now 8,000 feet. Eleven miles of track are laid in this mine.



near one of the entries and an eight feet Murphy fan is erected sending in 50,000 cubic feet of air per minute.

Ventilation is a most necessary feature of this mine, where gases are being given off so abundantly, to prevent the recurrence of the terrible accident which occurred in the old and now abandoned workings. The great prevalence and accumulation of gases there, may have been due largely to the mine being driven below water level, the gases being thus more confined. The present workings being above water level and dry and nearer the surface, it is supposed the gases find some exit through the surface shales. The coal being naturally full of gases, these will probably increase and accumulate with greater depth, and will need an abundant supply of fresh air to dilute and dissipate them as they are given off. As gases are given off from the "face" of the coal, the more the area exposed, the greater will be the accumulation of gas. "Blowers," or sudden bursts of gas may be tapped at any time, and abundant ventilation is necessary to dissipate them. Care is also necessary to prevent their taking fire, by the use of safety lamps, and the absence of all gunpowder or explosive material commonly used in development. Such precautions are being taken to prevent the repetition of that terrible catastrophe which is too fresh in people's minds to need recounting here, and a full account of which will be found in Inspector Mc'Neil's report.

The origin of these dangerous gases is partly a chemical and partly a geological matter. Carburetted hydrogen, or fire damp,  $\text{C H}_4$  and carbon dioxide, or choke damp, are common, principally in old mines that have attained considerable depth. Heat is the prime agent in distilling these gases from the coal. Such heat may be derived from three sources: first, the natural heat of the earth increases an average of one degree for every fifty or sixty feet; secondly, heat is produced by the mechanical folding and crumbling of rocks in process of upheaval, and thirdly, hot volcanic rocks are usually associated with such plications. The first will account in part for the prevalence of these gases in the deep mines of the old world. The two latter, and especially the last, will account for the presence of such gases in the coking coals of Crested Butte. "During the process of rock-



folding these gases," says Prof. Geike, "escape and the proportion of carbon progressively increases in the residue till it reaches the most highly mineralized anthracite, or may even pass into pure carbon or graphite. In the coalseams of Mons and Valenciennes the same seams which at the surface are in a state of bituminous coal gradually lose their volatile constituents as they are traced downward till they pass into Anthracite. In the Pennsylvania region the coals become more anthracitic as they are followed on to the Eastern region, where the rocks have undergone greater folding and were exposed to an elevation of temperature." We see here then a connection made between the process of gradual change from a bituminous to a coking coal, and from that to anthracite and the evolution of gases due to the heat evolved in the violent folding to which this region has been subjected, and to the heat engendered by volcanic eruptions.

The coking coal of Crested Butte has been subjected to a moderate heat from the proximity of the volcanic mountains back of it, and also from a certain amount of plication. Lava below the surface retains a latent heat for an enormous time after all eruption has ceased. This heat from a distance has, we think, slowly and partially changed the coal, and in doing so has evolved gases still retained in the strata or stored away and accumulated in cavities, pockets and crevices, such as the crevices on the line of a fault or between the roof and the coal. The old workings encountered such faults and crevices with depth and hence the "blowers." Gas in the old mine came principally from the roof. On the other hand, the anthracite mine has no gas, because it has been subjected to greater heat and the gases thoroughly driven off, have escaped. "The proportion of carbon has progressively increased on the residue" till it has become anthracite. In other words the coking coal is half cooked and retains its gases; the anthracite is thoroughly "done" and its gases driven off.

Doubtless the coal of this mine contains the greatest amount of dangerous gas in the State. The other mines of Colorado are generally free from it, especially those on the plain and border. Probably this is owing to less folding of rocks and less manifestations of volcanic agencies there, and to the general character of the coal being more lignitic or bituminous and



unmetamorphic, and not evolving gases, and also not generally coking. The other coking area at Trinidad probably derives its coking qualities from the same source as at Crested Butte, viz: the proximity of eruptive rocks. The coal, however, does not give off anything like the same amount of gas, if any at all; and if it did, it would be at once diluted and expelled by the excellent natural ventilation of those mines. The New Line mine at Crested Butte is worked on the pillar and stall system. The main entry is cut somewhat diagonally to the face of the coal; the side entries work directly on the "face." The only disturbances so far encountered on the strata are a few "rolls," one of which crushes the coal down from six to two feet.

The coal of this mine is principally devoted to coke making, for which there are 125 beehive ovens, similar to those at El Moro, close to the mine. The coke produced is probably the best in the State, if not in the West, being compact, firm, not cellular, free from slate, with little sulphur and a moderate per cent. of ash. See analysis of these coals and cokes by Mr. Charles A. Gehrman, of the School of Mines, at the close of this article. It is claimed for it "that there is less ash in it than any other American coke; that it equals the English coke, and gives general satisfaction to all the smelters using it."

This mine produced in 1888, 155,966 tons of coal and 40,889 tons of coke.

The principal markets are Utah, Nevada, Idaho, Montana and other points west.

#### THE SEMI-ANTHRACITE AND ANTHRACITE MINES.

Passing up the valley, about a mile above the Crested Butte mine, on the west bank of the river are the openings of the Warner & Durango Trust Co. The coal is semi-anthracite. The seam is four feet thick, and the mine was shut down at the time of our visit. A few feet below the coal are fossil and sea weeds, "Haly-menites," in the "fucoidal yellow sandstone," and the same is traceable on the opposite river bank below the Anthracite Mesa, which shows these coal seams to be the same as the lower seam worked at Trinidad and on the plains. But one seam, I think, is worked



in this valley. It diminishes in thickness as we ascend the valley, and becomes more anthracitic. From this to the head of the valley the marine Cretaceous shales underlying the coal are exposed, changed by heat into slates, but bearing unmistakable impressions of *Inoceramus* shells, characteristic of Cretaceous No. 4. Up "O Be Joyful" Gulch Mr. Holmes found in 1874, a bed of semi-anthracite two feet thick, between beds of quartzitic sandstones and metamorphosed shales, and 1500 feet above the level of Slate River. Its analysis is given as :

Water . . . . .	4
Volatile matter . . . . .	14
Carbon . . . . .	74
Ash of a reddish color . . . . .	8

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From this we cross the river to the east bank and ascend the steep slope of the Anthracite Mesa, which is 1500 feet above the river. The coal area, which is in the upper 500 feet, occupies about one square mile. The hill is composed for 1000 feet of metamorphosed shales, capped with a sandstone belt, upon which rests the coal seam. Above this are 500 feet of coal strata of slates and sandstones and coal seams. There is no lava cap or dyke immediately associated with this hill, though it may once have existed and been eroded off, as it is visible on the corresponding side of the valley. The metamorphic heat may have been derived from the proximity of Gothic Mountain and its dykes a few miles east of it. Slate river runs northwest and southeast, and the coal dips southwest toward the canon  $5^{\circ}$  or  $6^{\circ}$ , allowing a fair down grade for the loaded cars to the entrance. On the east side of the mesa, where the coal is cut off by Washington Gulch, it is said to dip to the southwest  $16^{\circ}$ . Possibly Gothic and Crested Butte are responsible for this elevation. The mine is opened by double entry on the face of the mountain, 800 feet above the coal-breaker and 1000 feet above the river. The coal is run out of the mine on a down grade of  $5^{\circ}$  and thence discharged on a double tramway 1600 feet long on a grade of  $30^{\circ}$ . The output is 250 tons daily,\* and the coal comes out in large solid masses

\* The production for 1888 was 36,000 tons of anthracite.



and is transferred to the coal breaker at the bottom of the tramway, where it is broken up in a crusher, something like a quartz crusher, from which it passes into revolving screens with meshes producing five different sizes.

No. 1, about the size of a man's fist.

No. 2, Orange size.

No. 3, Walnut.

No. 4, Pea coal.

No. 5, Culm or waste left on the dump, but not breeding spontaneous fires as is common with the "slack" of bituminous coal.

A branch of the Rio Grande Railroad runs up Slate Valley to the Breaker. One hundred men are employed. The company is "The Colorado Fuel Co." The shales of clay forming the roof of the mine are baked to such a degree of hardness that they form an excellent roof and no timbering is required. The floor is equally good. The seam is over four feet thick. There are four east and three west double entries, with rooms averaging 600 feet. The rooms run in 100 yards from each entry, are twenty feet wide with pillars of coal between them 20x30 feet. The air of the part of the mine I visited was good, no noxious gases are given off by the coal. Ventilation is by furnace in one of the entries, carrying 30,000 cubic feet of air per minute, communicating with the surface by a twelve-foot shaft and iron smoke stack. There are said to be four seams also in this hill, the same as at Crested Butte, one near the top of the mountain, one sixty feet above the worked seam, three feet thick, and one a few feet below it. All of them are anthracite. The seam worked is doubtless the same as that at Crested Butte. The coal breaker, the only one in Colorado, is an elaborate affair, after the fashion of those used in anthracite mines in Pennsylvania.

From the Anthracite Mesa we can trace the anthracite seam across the cañon, rising to a greater height as it is traced north to Poverty Gulch. The opposite side of the valley is a lofty mesa, 2500 to 3000 feet, composed of a series of benches and terraces; the lower portions are black metamorphic Cretaceous slates with *Inoceramus* shells, the terraces above this are sandstone and intrusive beds of quartz-porphry standing out



according to their relative hardness. Dykes also appear cutting through the strata and sending out intrusive sheets of porphyry.

The anthracite coal must be looked for in the upper portion of the mountain, from 1500 to 2000 feet above the creek. The dividing line between the coal bearing strata and the marine slates is well defined by a bench of sandstone which forms the floor of a wide amphitheatre at the head of Poverty Gulch. Here we found an anthracite seam, probably two to four feet thick, overlaid by twenty feet of sandstone, resting on which was a bed of porphyry, doubtless the immediate source of heat-producing anthracitism. The coal runs high in fixed carbon. (See Analysis No. 7.)

Cascade Mountain, between Poverty Gulch and Augusta Mountain, is a fragment of coal and Cretaceous strata, faulted off from the main ridge. The mountain is a net-work of dykes and intrusive sheets of porphyry, apparently crossing one another. The sandstones are changed to quartzite, the shales to slate; and the whole mass seems to have been subsequently shattered by minor faults. Mineral veins occur in it.

Similarly the walls surrounding the amphitheatre above the anthracite seam are riddled with dykes. The horizontal coal strata are in places caught up in the fiery embraces of a huge dyke and peep out from the blacker slates.

A wide amphitheatre is also at the head of Augusta Mountain, from which descends a series of deep benches like steep stairs into the valley. The Augusta silver mine is at the top and a tramway on the endless rope and bucket system,  $1\frac{3}{8}$  miles in entire length, brings down the ore from the mine. The ore of this and others near by is varied, producing fine grained galena, ruby silver, copper and iron pyrites, native and brittle silver, sulphurets and gray copper. The principal mines of Poverty Gulch are the Augusta, Jacob Strader, Gift, Big Strike and Domingo. I am indebted to Mr. Robinson, of Pittsburg, for his guidance over the mountain.

#### BOG IRON ORE.

About three miles up Coal creek, on the road from Crested Butte to Irwin, is a deposit of bog iron ore. It occurs by the



side of the road in a marsh thickly covered with moss and fallen timber. Where trees have been torn up by the roots or shallow prospect holes are dug, the soil is impregnated with iron oxide, and the pools and streamlets are red with the same mineral. The oxide solidifying in spongy masses, encloses the rootlets of trees and moss. There is a low bluff on the marsh of the same character. Both marsh and bluff are thickly strewn with boulders of porphyry drift. The iron is brought down by water passing through a large vein of pyrites higher up the mountain dissolving the pyrite and depositing it as an oxide in the swamp. I could not estimate the thickness or the exact area of the deposit. Prospect holes three or four feet deep had not reached bottom. The marsh and bluff rise about fifty feet above the road. Judging from rusty streams issuing for a distance of one-half a mile, it might be one-half a mile square. A survey I found of it, makes it 4880 feet long by 2320 feet wide.

The ore is used by the Colorado Coal & Iron Company, for refining gas at the gas works. It runs over fifty per cent. in metallic iron.

#### IRWIN.

From thence I rode to Irwin. Here are painful relics of the former overrated boom which has abandoned this camp, in the form of capacious and silent stamp-mills, substantial frame houses and stores, deserted or fallen in, of a once booming little town now but a small village. I put up my horse in the deserted store of the "Reasonable\* (?) Abe" and fed him off the counter!

There are some good mines and prospects here worthy of a steady camp. Such are the Forest Queen, Ruby Chief, Bullion King and others. They are located mostly at the contact between porphyry dyke and intrusive beds, and Upper Cretaceous sandstone. The veins are true fissures. Faults have occurred in some, leading to expensive prospecting for the true vein. The gangue or crevice matter is a hard quartz, sometimes brecciated with slate and containing numerous geodes and pockets of quartz crystals. The vein of the Forest Queen varies in width from five

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\* This "Reasonable" gentleman in skipping the region left behind him a vast accumulation of debts.



to twenty feet ; is nearly vertical and at contact between a porphyry dyke and Cretaceous sandstone. The ore is arsenical pyrites, with antimony and brittle silver. Reduction works are on the plant. Some rich surface "sulphuret" ore occurs as an alteration product on the surface, "playing out" as it passes down into unaltered combinations. An anthracite seam of excellent quality and fair thickness occurs near hear on Anthracite creek. It is described in the United States Survey Report of 1874 : "The coal is exposed on both sides of the creek. The beds are tipped up about  $25^{\circ}$  against the eruptive range, forming the divide between Anthracite and Ohio creeks. The coal is four to five feet thick, and probably the same as at Coal creek. An eruption of lava occurs 100 feet above the coal, and probably so heated as to deprive it of bituminous matter, and change it to anthracite. An analysis gives :

Water . . . . .	2.00
Volatile matter . . . . .	2.50
Fixed Carbon . . . . .	91.90
Ash, reddish . . . . .	3.60"

The mine is not working at present owing to the distance from the railroad.

On Rock creek the coal alluded to is an anthracite. Above it is a mass of eruptive rock. The coal is five feet thick. Analysis :

Water and volatile matter . . . . .	7.40
Fixed Carbon . . . . .	88.92
Ash, reddish . . . . .	3.68
	<hr/>
	100.00

ANALYSES OF COALS FROM THE CRESTED BUTTE REGIONS BY CHARLES A. GEHRMANN, OF THE SCHOOL OF MINES.

*Prof. Arthur Lakes, State School of Mines :*

DEAR SIR : I herewith submit the results of analyses of coals submitted to me, together with a few remarks as to their comparative value so far as determinable by chemical examination.

Yours Respectfully,

CHAS. A. GERHMANN.

GOLDEN, COLO., January 1, 1886.



The coals named in the present report are all from the neighborhood of Crested Butte and include both the coking and non-coking bituminous coals from the mines of the Colorado Coal & Iron Co., the coke made from the former, in the company's ovens, and three examples of anthracite and semi-anthracite. The method of analysis employed was that which is ordinarily used and known as "proximate" analysis.\* No other explanation is deemed necessary, as the method is familiar to all analytical chemists. The samples compare very favorably with the best Eastern coals. Especially is this true of the coking coal, which in general composition is equal to the best Eastern gas coals. The coke produced from this coal, as seen by the analysis, contains somewhat more ash than would be calculated from the analysis of the coal. Possibly the coal sample was above the general average of the mine, but the coke analysis (No. 3) is better than that of most American coke, when fairly sampled, as this was, from large lots. The sulphur was in each case estimated in a separate portion and is of course included in the summations of the "proximate" analyses

No. 1. Surface coal of upper seam, South end of C. C. & I. coal mountains, near Baxter creek, (non-coking):

Moisture . . . . .	6.53 per cent.
Volatile . . . . .	51.41 "
Fixed carbon . . . . .	39.81 "
Ash . . . . .	2.25 "
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	100.00

Color of ash, white.

Sulphur, 0.437 per cent.

No. 2 Coking coal of C. C. & I.:

Moisture . . . . .	1.17 per cent.
Volatile . . . . .	36.80 "
Fixed carbon . . . . .	58.01 "
Ash . . . . .	4.02 "
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	100.00

Color of ash, reddish brown.

Sulphur, 0.454 per cent.

\* Hinrich Geol. Survey of Iowa Chemical Report



No. 3. A second sample of the C. C. & I. coking coal from entry No. 6:

Moisture . . . . .	1.94 per cent.
Volatile . . . . .	38.18 "
Fixed carbon . . . . .	56.80 "
Ash . . . . .	3.08 "

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100.00

Color of ash, salmon.

Sulphur, not determined.

No. 4. Coke (made from above coal):

Moisture . . . . .	0.05 per cent.
Volatile . . . . .	1.15 "
Fixed carbon . . . . .	89.12 "
Ash . . . . .	9.68

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100.00

Color of ash, light reddish brown.

Sulphur, 0.523 per cent.

No. 5. Semi-anthracite, from near Warren's coal bank:

Moisture . . . . .	0.64 per cent.
Volatile . . . . .	11.88 "
Fixed carbon . . . . .	82.70 "
Ash . . . . .	4.78 "

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100.00

Color of ash, reddish brown.

Sulphur, 0.955 per cent.

No. 6. Anthracite coal, from anthracite mesa two miles northwest of C. C. & I., on east bank of Slate creek:

Moisture . . . . .	0.72 per cent.
Volatile . . . . .	6.36 "
Fixed carbon . . . . .	86.92 "
Ash . . . . .	6.00 "

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100.00

Color of ash, reddish brown.

Sulphur, 0.763 per cent.



No 7. Anthracite seam, in Poverty Gulch (from surface) :

Moisture . . . . .	3.47 per cent.
Volatile . . . . .	2.63 "
Fixed Carbon . . . . .	88.32 "
Ash . . . . .	5.58 "
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	100.00

Color of ash, reddish brown.

Sulphur, 0.438 per cent.

## COLORADO ANTHRACITE.

BY PROF. J. S. NEWBERRY.

The Anthracite coal mine near Crested Butte, has now been worked for several years by the Colorado Fuel Company, has railroad connections with the Denver market, and its product is there a well know staple. The coal seam is from four to six feet in thickness and the coal is a hard bright anthracite, resembling in appearance and not inferior in quality to that taken from the Pennsylvania mines. The area above the valley of Slate river available for working is about 500 acres. Perhaps the mountain opposite the Anthracite mine may be found to contain more than is yet known to exist, but without further discoveries, it would be unsafe to estimate the coal area of Slate river valley at more than 2000 acres.

At Irwin 14 miles west, there is an area of anthracite of 1500 to 2000 acres. The coal is of good thickness and quality, as silvery and brilliant as any from the Lehigh basin, but this field has as yet no outlet by railroad. The anthracite of Gunnison Mountain, of which so much was hoped, has proved to be very limited in quantity, and is for the present quite inaccessible; that of Ragged Mountain, still farther north, is open to the same objection, and though of good quality, is shown by the investigation of Mr. R. C. Hills to be cut off at no great distance in the rear of the outcrop by the eruptive rocks which have metamor-



phosed it, and the quantity is therefore small. The Muncie anthracite, north of the last mentioned locality, has been purchased by the Midland Railroad, but it is questionable whether it will prove sufficient in quantity and quality to warrant the large expenditure necessary to open a way to it.

The localities enumerated include all the important deposits of anthracite coal yet known in Colorado. From its mode of formation the area of anthracite must necessarily be small. It is confined to the localities where the eruptive rocks have burst through the coal series, and the influence they have exerted has been sufficient to produce anthracite only for a short distance. Hence we may conclude that the anthracite of Western Colorado, excellent as it is in quality, is not destined to be an important factor in the future history of the State.

## ANALYSES OF ANTHRACITE BY PROF. J. S. NEWBERRY.

## Anthracite of the Anthracite Mesa, Crested Butte.

Moisture . . . . .	1.56
Volatile matter . . . . .	5.93
Fixed Carbon . . . . .	88.76
Ash . . . . .	3.75
	<hr/>
	100.00
Sulphur . . . . .	0.48
Phosphorous , . . . .	0.067

## IRWIN ANTHRACITE. (IRWIN).

Moisture . . . . .	2.77
Volatile matter . . . . .	6.55
Fixed Carbon . . . . .	84.81
Ash . . . . .	5.87
	<hr/>
	100.00
Sulphur . . . . .	0.79
Phosphorous . . . . .	0.027



## GUNNISON UPPER SEAM OF ANTHRACITE.

Moisture . . . . .	0.09
Volatile . . . . .	9.68
Fixed Carbon . . . . .	81.93
Ash . . . . .	8.30
	<hr/>
	100.00
Sulphur . . . . .	0.547
Phosphorous . . . . .	0.039



## CHAPTER X.

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Coals of Gunnison Mountains.







## Chapter X.

COALS OF GUNNISON MOUNTAINS.—BY PROF. J. S. NEWBERRY.

West of Crested Butte the Laramie coal series is pierced by several great masses of volcanic rock, a rhyolite, light gray in color, with numerous large, often opalescent crystals of Sanidin feldspar. This composes Mt. Beckwith, Mt. Marcellina, the Ragged Mountains, Mt. Gunnison, etc., with numerous dykes and intrusive sheets which penetrate the sedimentary strata to some distance from the volcanic vents. From these mountains one looks out westward on to the broad plateaus of Grand and Battlement Mesas, an unbroken portion of the sheet of coal-bearing rocks which occupies all the interval to the Wasatch. Between the eruptive masses the strata are generally much warped and broken, but along the North Fork of the Gunnison, in many places, they lie nearly horizontal, the coal-beds being above drainage and accessible. On the east side of Mt. Gunnison a plateau of this character forms the most interesting and valuable tract of coal land I have anywhere seen. Coal creek cuts into this plateau to the depth of 500 to 1000 feet, exposing at the bottom the Colorado Cretaceous shales, and above them the base of the Laramie, soft, yellow sandstones and gray argillaceous shales. Near the top of the cliffs lies an intrusive sheet of rhyolite, similar in general appearance and relations to the Palisades on the Hudson river.

In this section, in addition to smaller beds, are four finer coal seams than I have elsewhere seen in one exposure. Of these the first and lowest is 10, the second  $13\frac{1}{2}$ , the third 10, and the fourth 10 feet in thickness. The uppermost lies within a few feet of the trap sheet, and at places this comes down immediately upon it, converting it into anthracite. The third seam is 25 feet below the fourth, and they are much alike in character. The second seam from the bottom is 13 to 15 feet in thickness, having been somewhat eroded by the current which spread over it the



material of the sandstone roof. This has one parting, a band of "smut" four to six inches in thickness, about six feet above the base; a good feature on the seam, as it will permit its being worked on two benches, and make the "bearing in" under the upper bench easy. With the exception of this parting the coal is very homogeneous and pure. Like many other Laramie coals this contains numerous particles, scales or lumps of a yellow resin which resembles amber, but is a secondary product, having been distilled from the substance of the coal long subsequent to its formation, accumulating in its joints and cavities.

The character of all the coal seams on Coal Creek is similar, though the upper seams are somewhat dryer from their proximity to eruptive trap rock. All are hard, bright, and homogeneous, working large and coming out in blocks like quarry stone. To the experienced coal-miner nothing could be more attractive than the solid, black, shining walls they present when opened.

In composition these coals are most like our open-burning bituminous coals of the Alleghany coal fields, but contain more gas, and show little tendency to coke. They contain four to five per cent. of water, and from four to seven per cent. of ash; the second and fourth seams one-half per cent. of sulphur; the third nearly one and one-half per cent.; in phosphorous they are all low. The lowest seam of the series is not as well shown as the others but it is apparently softer and will probably coke better.

The coals of the country drained by the North Fork, where not locally converted into anthracite, are exemplified by those just described. Some of them will coke, but they must be generally classed as open-burning. Whether they can be used in the raw state for smelting remains to be seen, but in my judgment with proper appliances and management this may be done. As steam coals and household fuels they have no superior, and it will not be many years before they will be taken through the mountains by railroads in large quantities to supply the ever increasing want of good fuel in the Prairie States.



ANALYSES OF COALS OF THE GUNNISON MT. DISTRICT,  
BY PROF. NEWBERRY.

GUNNISON UPPER SEAM 10 FEET THICK.

Moisture . . . . .	3.803
Volatile Matter . . . . .	40.155
Fixed Carbon . . . . .	51.178
Ash . . . . .	4.341
Sulphur . . . . .	0.523
	<hr/>
	100.000
Phosphorus . . . . .	0.029

GUNNISON UPPER SEAM, ANTHRACITE.

Moisture . . . . .	0.910
Volatile Matter . . . . .	9.313
Fixed Carbon . . . . .	80.932
Ash . . . . .	8.298
Sulphur . . . . .	0.547
	<hr/>
	100.000
Phosphorus . . . . .	0.039

GUNNISON SECOND SEAM, 10 FEET THICK.

Moisture . . . . .	4.93
Volatile Matter . . . . .	38.83
Fixed Carbon . . . . .	47.91
Ash . . . . .	6.94
Sulphur . . . . .	1.39
	<hr/>
	100.00
Phosphorus . . . . .	0.054

GUNNISON THIRD SEAM, 13½ FEET THICK.

Moisture . . . . .	5.23
Volatile Matter . . . . .	41.92
Fixed Carbon . . . . .	48.43
Ash . . . . .	3.95
Sulphur . . . . .	0.47
	<hr/>
	100.00
Phosphorus . . . . .	0.080



## BALDWIN MINES.

On Ohio creek, eighteen miles from Gunnison, along the line of the Denver, South Park & Pacific Railroad, the Baldwin Mines have been for some years operated by the Union Coal Company. According to the inspector's report the seam is 4 feet 6 inches wide, of semi-bituminous coal dipping  $4^{\circ}$  and developed by a shaft 150 feet deep. At 106 feet from the surface a small seam is encountered about one foot thick, followed 30 feet below by the main seam somewhat as at Golden and Louisville. Below this lies a heavy body of sandstone. The production for 1888 was 14,174 tons.

Another mine on the same creek owned by the Ohio Creek Anthracite Company, lying to the west of Mt. Carbon and twenty miles from Gunnison City, finds the seam 4' 6" of bituminous coal dipping  $35^{\circ}$  and outcropping in the mountain side 400 feet above its base. A cross cut turned 8' 6" wide by 7 feet high is driven in 1150 feet on a gentle grade to drain the mine and intersect the coal seam. Where it intersects the latter levels are run north and south on the edge of the seam. The coal left above will be stoped out by rooms and pillars, chutes being let down to hoppers on the main level to the pit cars. Twenty coke ovens have been constructed and more are in process of erection. A branch line from the Denver and South Park road is expected to this point.

"The coal field commences south of Mt. Carbon in a wedge-like shape, widening until it covers a width of sixty miles, and extends over 100 miles in length in the direction of Grand Junction. Portions of this field are also found near Ouray along the skirts of the San Juan Mountains. The coal varies in quality, being poor where the covering is light and becoming more bituminous where it is heavily covered and even anthracitic as it approaches the neighborhood of volcanic action. The bituminous coking coal is generally found in proximity to the anthracite districts and the lignitic or inferior coals cover the larger areas."



## COALS OF THE WHITE RIVER COUNTRY.

"These are simply an extension northward of those which crop out on Grand river, and they have been opened at various intermediate points." Large bodies of such coal are said to exist in the neighborhood of Meeker, some fifty miles north of Newcastle, but according to Mr. R. C. Hills they are inferior in quantity and quality to those found in the country between Glenwood Springs and Gunnison. The reason for their inferior character may be the comparatively undisturbed nature of the strata of those regions.

Says Prof. Newberry: "In going down the Grand river from Piñon Basin the Laramie coal series is found continuously to Grand Junction and thence westward to the Wasatch. Much of this country I have been over and have examined the coal in a great number of localities, and while the seams are of good thickness and fair quality in many places, they are less thick, and the coals are less varied and pure than in the belt of country between Glenwood and Gunnison. At Coalville, Castle Valley, Pleasant Valley, Cedar City, and Kanawa, are seams of coal which have already been somewhat worked and have been proved to be of fair and sometimes of excellent quality. The same is true of the country bordering on the Union Pacific Railroad, where at Evanston, Rock Springs, etc., large quantities of coal are mined which is much esteemed for domestic fuel and for the generation of steam. Yet nowhere in all this region is the coal equal in quality, quantity and variety to that found in the country between Grand river and the Gunnison. Adding to this belt the coals of White river and the intervening district, we have some 4,000 square miles of coal land in western Colorado which will bear comparison with any equal area of Carboniferous coals in the valley of the Mississippi. The importance of this coal field to the inhabitants of Colorado and the adjacent prairie region cannot be overestimated; and however productive the mines of gold and silver of this highly favored State may become, I cannot but think that her coal mines will prove the most important source of her wealth."



GENERAL REVIEW OF THE NORTHWESTERN COAL FIELDS OF  
COLORADO, BY MR. HEWITT.

"This portion of the State, being the northern half of its Pacific slope, is drained by four rivers, the Gunnison, Grand, White and Yampa or Bear, which, with the Green, flowing south from Wyoming, unite to form the Colorado. These streams, fed by the snows of the Rocky Mountains, fall from an altitude of 10,000 to 12,000 feet, at their sources, to 4,000 feet, at the confluence of the Grand and Green in Utah, near the State line.

This area, about 150 miles square, was the scene of great development in the period subsequent to the Carboniferous; but earlier formations have meagre representation. The whole geological section is torn and contorted in every period up to the most recent, by the movements that made the Continental divide and many outlying peaks and high plateaus.

A single instance may serve to illustrate the extent of this action. The Silurian limestones are lifted and partially eroded to form a plateau fifty miles across, between the Grand and White rivers, three thousand to five thousand feet above their level and fifty miles west of the range.

The direction of all these rivers was determined by anticlinal cracks and fissures, since eroded with canons of 2,000 to 3,000 feet in depth. These streams and their tributaries show abundant evidence of glacial action, to which is largely due the extent of the arable land in upper benches and mesas. Until 1882 nearly all this area belonged to the Ute Indians.

Where the Carboniferous measures are exposed, they have been crushed and twisted between the heavy limestones and quartzites below, and the enormous Jura-Trias above; and though they contain coal, it is extremely unlikely that any of it possesses commercial value. The Jura-Trias red sandstones are 3,000 to 5,000 feet thick, and their fractures have cañoned all the streams of the Piedmont region at least once in their course. On top of these, separated by the *Atlantosaurus* shales, is the Dakota sandstone, a very prominent ledge, 50 to 100 feet thick. In this sandstone is the horizon of a coal seam that may be of value between the White and Yampa Rivers and elsewhere.



Above this ledge are 1,500 to 2,500 feet of Colorado and Fox-hill shales, that when upturned, are easily eroded, and have formed a chain of parks below the coal measure sandstones.

The productive Cretaceous coal measures are 700 to 1,200 feet thick and contain two, possibly three series of coal seams.

Above the coal, the softer sandstones and shales of the Post-Cretaceous, about 1,000 feet thick, have usually been eroded to gentle slopes.

Over the larger part of the basin, the section is increased by at least 3,000 feet of Tertiary measures, containing some petroleum shales that, when fresh, yield, on heating, considerable vapor.

Since the region was outlined by fractures that determined the courses of the rivers, many basaltic overflows have occurred; and, as these cap all the geologically and topographically high ground, it is probable that the whole basin was so covered. In the bed of the Eagle river, above its junction with the Grand, near Dotsero station, is a lava flow so recent that though the bed of the stream was changed by it, the edge is almost intact, and the adjoining partially vitrified shale has not been eroded.

The coal measures underly most of this region in two great fields; one extending from the north side of the drainage basin of the Gunnison to the southern water-shed of the Yampa, with the eastern and northern outcrops thrown up to from 30 to 90°, and the southern flat; the other a part of the Green river, (Wyoming,) field, extending into this State about 40 miles on the upper Yampa river.

As far as observed, these coal seams where unchanged by flexure with consequent heat and pressure, carry a lignite containing from five to twenty per cent. of water; so that it is probable that the better coal will be found only on the narrow east and north margin where the pitch averages 45°. In the southeastern corner of the field, on the head waters of the Gunnison, the seams are horizontal, but, being in narrow and detached patches have been locally metamorphosed so that in four miles the same seams are anthracite, coking, and dry coal.

Going north from this point, anthracite is found in patches high on the sides of Mount Marcellina and the Ragged Moun-



tains. The last peak of the latter, Chair Mountain, carries on its northern slope from 9,000 feet altitude to 10,000 feet, a tongue of outcrop that is proved to be anthracite. Two seams only of the lower series are left from erosion, and but one is possibly of workable thickness.

Five miles north, on the opposite dip, the seams come up on Rock creek as coking coal; from here the outcrop turns to the west around the topographical basin of Coal creek, caused by the protrusion and erosion of Colorado shales, the coal measure sandstones dipping outward in cliffs 1,000 to 2,000 feet high. In this basin, the coals are extremely fat, and produce a hard, bright, sonorous coke.

Going north from this disturbance half a mile, the measures again dip to the west under the influence of the fold that made the anticlinal valley of Rock creek and Roaring Fork, and continue so for twenty-three miles northward to the Grand river, at an average pitch of  $45^{\circ}$ , and as a ridge a thousand feet higher than the parks of the Colorado shales to the east. This stretch of outcrop, intrinsically a most valuable part of the field, is cut by three streams that can be used by railway lines, viz: at six miles from the basin by one fork of Thompson creek; one mile further by another; and six miles further by Four Mile creek. All these gaps have an altitude of about 8,000 feet, necessitating eight or ten miles of four per cent. grade to get up to them from the Roaring Fork valley, whose altitude is about 6,000 feet. About opposite Glenwood Springs in the Newcastle district the measures come under the influence of the great uplift of the White river plateau to the north, around which they describe a wide circle for sixty-nine miles, and, standing at  $50^{\circ}$  to  $90^{\circ}$ , are known as the great Hogback. In that distance the coal measures are accessible at eight gaps; but the conditions have nowhere been such as to produce coking coal.

Sixteen miles northeast of the White River gap, at Meeker, under the erosion of the Yampa valley, the outcrop has lost the influence of the plateau, and is flat, with a western direction for thirty-two miles. Here the influence of the Blue Mountain is felt, and the outcrop is bent to the south for twelve miles to the White river; then it follows the foot-hills as a hogback to the



State line a distance of thirty-four miles in a westerly course with but two gaps. Near the State line and just south of this hog-back on White river, at the mouth of Douglas creek, there is an upheaval similar to that of Coal Basin, but of less violence, and without the conditions to change the character of the coal from dry to coking.

The geographically valuable parts of this 200 miles of outcrop are the eastern and western, and most of the intrinsically valuable coal is in the southern ten or fifteen miles.

The southern outcrop of this field begins on the headwaters of the north fork of the Gunnison, a few miles west of Coal Basin, where the beds are flat and the erosion great; thence following that river, receding as it falls, it crosses the Grand fifteen miles above the confluence and takes its direction into Utah.

In this field, as elsewhere in the State the *Halymenites* *Fucoidal* sandstone is the only datum that approaches persistency. It varies from a compact, hard white sand rock to a coarse sandy shale, and over thirty miles of the southeastern outcrop the fossil bed on top of it is quite persistent. But it is not always the base of the coal measures. At one place, west of the Grand, there are two workable coal seams below it. In fact all the measures of the section lack persistency and except a liability of recurrence of two heavy sandstones enclosing the upper series of beds, a section in one gulch shows no resemblance to the next one a couple of miles away. There is no limestone in the measures, though many of the sandstones are impregnated with lime and gypsum.

The 150 to 200 feet of sandstones and shales above the *Halymenites* sandstone always contain two and often three or four workable seams and occasionally two or more come together and form a large and usually dirty seam.

Thorough prospecting on ten miles of outcrop north of Thompson creek, has shown that no seam remains workable in size a greater distance than two miles, and usually not half that distance. All the seams except one, and that worthless, are nearly as variable in character and marking as in size. These facts, with a cross faulting every 4000 to 6000 feet of from 30 to 275 feet, make it difficult to say which of these beds are main



seams and which splits. Whether the upper part of the measures should be divided is not certain. In many places there are two distinct horizons at which seams recur, but at three points of economical importance, considerable prospecting disclosed but one, at 600 feet above the lower series. Development there shows that this series is more irregular and patchy than the lower one.

It seems altogether probable that the break throwing up the outcrop occurred near the margin of the original field of deposition, because the size and number of the measures is greater where the erosion has been further from that line.

All the seams are coking coal, from Coal Basin north twelve miles, or about six miles either way from a point opposite to Sopris peak, six miles distant, and the termination of the Elk Mountains, a spur of the main range. This peak has an altitude of 12,800 feet, it is an eruptive outbreak, the center of four radiating anticlinal valleys, and the heat from it may have been directly or indirectly the cause of the coking quality of the coal seams, they are certainly most "fat" immediately opposite it, and around the coal basin upheaval. Also the lower coals are the fatter.

On the northern edge of this influence half a mile of development shows a gradual change from a good coking coal to a dry coal that with ordinary bee-hive treatment will barely agglutinate. In another half mile the same seam is dry. In this transition area, a small cross fault makes the coal "fat" for twenty or more feet on either side. The dry seams also present wide chemical and physical changes in short distances; a soft and loosely bedded coal has in 100 feet become compact and hard without the intervention of a fault. A couple of hundred feet has reduced the water combination from twelve to five per cent. In seams of coal free from binders of slate or bony coal, the squeezing during upheaval has obliterated the cleavage and often the bedding. The floor and roof of the seams are generally more or less of shaly clay slate that slacks and crumbles on exposure. These facts, together with a steepness of dip make mining difficult; and extensive development will demand the modification of any system now in use in the United States."



## CHAPTER XI.

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Geology Between Gunnison  
City and Ouray.







## Chapter XI.

### DESCRIPTION OF GEOLOGY BETWEEN GUNNISON CITY AND OURAY.

From Gunnison City we go by train to Ouray. The region about Gunnison City as we go west is characterized by table lands and plateaus, most of them capped by lava or volcanic breccia which rest sometimes directly on upturned granite and sometimes on relics of Cretaceous strata that once covered the granite but have been largely removed by erosion.

Between Gunnison City and Sapinero station on the Denver & Rio Grande railroad, we enter a cañon through several hundred feet of variegated marls and shales resting on the granite. The series is capped by some 300 feet of volcanic breccia overlaid by a hundred feet or more of lava in two flows or sets of pillars. In the marls and shales are some dark lines which may indicate the presence of coal.

This short canon is an introduction to the noted Black Canon, one of the most picturesque in Colorado, which we presently enter. The walls are of massive jointed granite and bedded gneiss. The bedding and other characters did not seem to us quite to correspond on either side, and if this be the case the origin of the canon may have been along a line of fault, the rest being the work of erosion. The celebrated Curricanti needle so often seen in pictures and photographs, is a pyramid or obelisk of granite separated from the main mass by the erosion of two side canons. The canon is cut down deep beneath the horizontal table lands of the region and is like a great rift below the lava-covered surface of the country. The entire region between Gunnison and Lake City is a monotonous plain of lava covered with sage bush with occasional outcrops of granite breaking through the surface of the once molten crust. From the scoriaceous, vesicular character of this lava it would appear to have been a surface flow.



At Cimarron station we emerge from the canon to find the drab shales of the Fox Hills Cretaceous resting upon and dipping off from the Archean granite in a westerly direction, and thence to near Ouray we meet only with the Cretaceous formations.

The entire absence of the older groups and the direct superposition of the Cretaceous upon the Archean granite in contrast to what we find on the eastern border of the mountains, where older strata generally intervene, seems to imply that this portion of Colorado, for an indefinite distance into Utah, was above the ocean as a granite island or continental mass during the whole of those earlier periods when seas were depositing various sediments along the more eastern border of the present ranges, and that it was not until the Cretaceous period that by a probable subsidence of the region, the Archean land was sufficiently submerged beneath the waves to admit of its being covered by Cretaceous sediments.

The uplift since that period does not seem in this western part to have been so great or violent as along the eastern border, the beds being at a gentler dip which soon passes into horizontality, giving rise to the prevailing plateau character which extends west as far as the eye can reach.

We descend gradually into the country of drab and yellow shales towards the valley of the Uncompahgre river, and at Montrose take a branch line to Ouray, following the course of that river to its exit from the volcanic San Juan mountains, which rise above the monotonous plateau country in snow capped towers and terraced battlements, a few miles to the south. As we approach them the influence of their disturbance and uplift becomes apparent in the gradual steepening of the dip of the sedimentary strata. Between Dallas and Ouray we meet the characteristic yellow sandstone of the Laramie group resting upon the Foxhill shales and can see them stretching away like a girdle around the flanks of the San Juan mountains, attaining a thickness of over 1,000 feet, the upper section of which may possibly be Tertiary. The lavas and breccias of the San Juan appear in the distance to cap this formation. Indications of coal appear at the usual horizon above the basal sandstone, and some prospect-



ing appears to have been done, but so far as we could learn with no satisfactory results. The coal seams are said to be very narrow.

As we ascend the stream the uplift, combined with erosion brings lower strata successively into view. Beneath the Laramie appear the Foxhills and Dakota Cretaceous, followed by the Redbeds of the Jura-Trias, which latter appear to be thrown into two or more synclinal and anticlinal folds, and below these again are thick massive strata of brownish red conglomerate and paler belts of sandstone and limestone, belonging to the upper and middle Carboniferous, with limestones at the base probably Lower Carboniferous. All these groups of strata, together with the still lower Silurian and Cambrian quartzite and Archean granite, are, as we enter the mountains covered with prodigious volumes of volcanic breccia and other lavas to a thickness of from 3,000 to 5,000 feet, forming the San Juan mountain system, the individual peaks and castles resulting from the erosion of profound valleys and cañons out of a once lava deluged plateau.

A narrow cañon leads us to Ouray, the most picturesquely situated town in Colorado, located in a deep, wide pit or amphitheater in these mountains. This is hollowed out of the volcanic cap and underlying Paleozoic strata by glacier and stream. The massive layers of strata rise tier upon tier in the almost vertical cliffs surrounding the town, which are capped by the volcanic breccia. They are traversed by igneous dykes and horizontal sheets of lava welding the strata together as by iron girders.

One of these dykes, of a greenish porphyritic character, is seen on the walls of the canon as we enter, sending out from it intrusive sheets of lava between the strata, while on top of all rests the massive sombre gray volcanic breccia. The bulk of this display of red and white quartzite, conglomerate and limestone, appears to belong to the Carboniferous, the upper portion of it may be Trias. Near the northern entrance of the canon what is supposed to be the Dakota group metamorphosed into quartzite, carries in irregular cavities between the bedding planes and joints which have been enlarged by the action of water, quantities of sand and gravel containing considerable free gold, which has given rise to the recent gold excitement on what has been called



"The gold belt of Ouray." Intrusive sheets of porphyrite lie above this quartzite with feeding dykes running up to them, the whole being capped by remnants of the volcanic breccia. The location of the "gold belt" with the openings upon it are in plain view from the city, upwards of 1000 feet high on the cliff near the northern entrance to the town.

#### THE OURAY HOT SPRINGS.

Ouray has long been noted for its hot springs. They are located towards the upper end of the town at the base of the vertical cliffs, and issue from the limestone. The water is about 128° Fahrenheit. A flat terrace above the springs covering several acres, on which the upper part of the town is built, is composed of layers of spongy calcareous tufa some thirty to fifty feet thick, honeycombed with little cavities, and full of traces of comparatively recent fossil vegetation. This shows the former continuous action of the hot springs on a larger scale and over a much greater area than at present. The tufa is matter deposited by the springs derived from the underlying limestone. Swimming baths are established at the springs, and apart from its mining interests this pretty town, with its villas and fine hotels, has quite the air of a watering place.

From Ouray we enter the heart of the San Juan mountains through the cañon of the Uncompahgre river by the Mears road, which is a wonderful feat of engineering. The road is hewn for several miles out of the hard vitreous quartzite along the face of a vertical cliff looking down a thousand feet upon the boiling torrent in the bottom of the cañon. As we ascend the pass the Carboniferous limestones are succeeded by an enormous thickness of 13,000 feet of distinctly stratified quartzites, slates and schists. Part of these may belong to the Silurian and Cambrian series, but as these series combined rarely attain in Colorado, a thickness of 1,000 feet, so great a body at this locality is extraordinary, and to account for it, it has been suggested that part of it, *i. e.* the lower portion may, as in Canada, belong to the Huronian or Laurentian, upper divisions of the Archean not elsewhere represented in Colorado. The dip of these quartzites is



about  $75^{\circ}$  and to the north. Their uplifted crests have been deeply eroded, and in the hollows so formed rest the massive volcanic breccias for a thickness of from 2,000 to 5,000 feet.

It is evident that the eruption of these lavas must have occurred not only after the formation of these Paleozoic beds but also after they were uplifted into mountain forms. As we find strata of all ages even to the supposed Tertiary, covered by the eruptive rock, we may infer that some of these eruptions occurred after or during Tertiary times.

The breccia is composed of angular blocks of lava of all sizes and generally of an olive green or pinkish blue cemented together by a paste of the same material. These lava caps are traversed by great numbers of large quartz fissure veins running in parallel systems usually carrying more or less mineral and yielding the principal metallic wealth of the district.

All the way up the cañon we notice the effect of the glacier that once filled it, in the smooth rounded outlines of some of the rocks that formed its bed, as well as in the numerous parallel scratches or striæ left on the hard vitreous quartzite.

We arrive at last at the head of the gorge, climb over a steep bench and find ourselves in a flat meadow-bottomed valley leading to Ironton. In this valley are numerous swamps and ponds, the bottoms, weeds and floating timber of which are thickly incrustated with bog iron. The source of this iron is the pyrites and other iron bearing minerals with which the lavas are charged. The oxidation of this iron has painted the rocks of the surrounding mountains with brilliant orange, and vermillion and maroon colors and given the name of Red mountain to a particularly gorgeous locality. There, as well as at Ironton, large mining operations are carried on upon silver bearing fissure veins, the ore not unfrequently being found in a series of small caverns in the quartz veins. From Ironton a train carries us through the finest scenery in Colorado to Silverton and thence down the Animas cañon to Durango where as we have narrated, the great southwestern coal fields are to be seen. Thus we completed the circle and the grand tour of Colorado's principal coal fields.







CHAPTER XII.

The Park Coal Fields.







## Chapter XII.

### THE PARK COAL FIELDS.

Large bodies of coal are to be found in the South and North parks, which may be called isolated fields as they are cut off from the main fields by encircling mountains.

These "parks," as they are called, are a characteristic feature of the topography of Colorado. They are in reality broad valleys occupying lines of depression between different ranges of mountains, and owe their origin partly to geological structure and great geological movements, and partly to erosion. As the geology of these parks involves many of the main features of the geological structure of the Rocky Mountain system, we will quote in explanation Mr. Emmon's concise description of the general geology of these mountains. He says, in the census report of the Geological Survey :

"The mountain belt of Colorado, which in this latitude is generally known as the Rocky Mountains, to distinguish it from the other principal Cordilleran systems to the westward, the Wahsatch and the Sierra Nevada, has, taken as a whole, a due north and south trend. When examined in detail, however, it is found to be made up of a number of more or less regular chains or ridges having a general trend to the west of north, standing "en echelon" or with their ends overlapping each other, with mountain valleys of greater or less extent between them, as the result of which structure the mountains in general seem to be divided up into two chains, with large included valleys which have received the name of "Parks."

The general name of Colorado, or Front range has been given to the eastern of these divisions, and that of Park range to the western. The North, Middle and South parks and the San Luis valley are the larger of the included valleys, the three former, with the smaller Wet Mountain valley to the south, being



really a portion of the same continuous line of depression, while the valley of the Upper Arkansas stands in the same relation to the San Luis valley.

The eastern front of this range presents a comparatively regular north and south line, broken here and there by bay-like valleys, running up into the mountains in a northwesterly direction and following the prevailing trend of the echelon ridges. The most important of these are the Manitou and Huerfano parks, and that which extends up Oil creek from Cañon City. These in earlier geological times were actual bays in the seas in which the Paleozoic and Mesozoic rocks were deposited, while the parks were partially inclosed arms of those seas.

The western front of the mountains is more irregular and is broken by branching mountain groups extending out also with a general northwest trend into the 'Mesa' country of the Colorado plateau. The principal of these outlying mountain groups, commencing on the north, are the Elk Head mountains, the White River plateau, the Elk mountains, and the San Juan mountains, in all of which there is a very great development of eruptive rocks." The geological history is as follows: "At the close of the Archean era, or in the Cambrian ocean, a large area covering most of what is now the Colorado or Front range, formed a large rocky island with a number of smaller islands lying to the westward, the most important of which now forms the Sawatch, from which it was more or less completely separated by the waters occupying the present depressions of the North, South and Middle Parks.

During the whole of the Paleozoic and Mesozoic eras, a continuous sedimentation went on in the seas surrounding these islands, of material derived from the abrasion.

The geological record gives evidence of no great disturbance during this long period. Toward the close of the Cretaceous period at the time of the formation of the coal beds, the seas became shallower owing to a general elevation of land and considerable portions of the outlying areas were partially inclosed. During this time and possibly earlier, immense masses of eruptive rock were forced up through the already deposited sediments which were still beneath the water. Unlike the lava flows of



modern days however, these molten masses were not, as a rule, spread out on the surface of the rocks, but congealed before they reached it, either in large masses, in dykes, or in sheets forced in and spread out between the beds. These eruptions seem to have continued nearly to the close of the Cretaceous period.

At some time after the close of the Cretaceous period a general dynamic movement took place in the Rocky Mountains, by which the existing mountain ranges or islands were crushed together, broken and elevated, and considerable areas of the adjoining sea bed were lifted above the surface.

In the general continental elevation which followed fresh-water lakes or inclosed seas were formed in which, by the degradation or wearing away of the newly-made land areas, considerable sediments were deposited. The outline of these Tertiary seas, owing to the nature of the deposits made in them, which were easily eroded and carried away by subsequent atmospheric agencies, cannot be yet definitely determined. It can only be said that their area and location were frequently changed, and that during the Tertiary era and subsequent to it, eruptions of igneous rock occurred, generally following the lines of earlier eruptions, but unlike those, spreading out on the actual surface of the land, and in some cases beneath the sea.

While the general form of the mountain area as has been shown was determined in the very earliest geological times, it is only since the Tertiary era, and in a great measure by erosion subsequent to the Glacial era that the present sculpturing of the mountain forms and carving of the valleys have taken place."

#### THE SOUTH PARK.

It is a pleasant change and surprise after a day's ride up the Platte cañon, through fifty miles of Archean granite and gneiss of the Colorado range, to reach the brow of a hill and look down into the prairie basin of South Park, encircled with snow-capped mountains. The South Park is an oval basin about forty miles long by twenty miles broad. The general surface is varied by a series of parallel crescentic ridges or hogbacks, composed of the strata forming its floor, tipped up on all sides except the east by the elevation of the encircling mountains.



Parallel with these "hogbacks," or sometimes crossing them diagonally, are other steep ridges and "buttes" of brown eruptive rock which issued from fissures now occupied by dykes.

The crescentic axes of elevation form a quaquaversal of the strata, dipping generally towards a common centre, which lies toward the eastern portion of the park and which is more or less horizontal.

The basin so formed is not complete on the east side, nor so far as known do the strata tip up there as we should expect them from the elevation of the Front range.

The explanation of this may be, the existence of a fault running along the eastern part caused by the strata in the process of elevation being broken, and slipping down from the granite; proofs of this, however, are obscured by drift and vegetation.

The valley plains are covered by sedimentary strata of Mesozoic age, which, with the underlying and conformable Paleozoic formations, slope up to the crest of the Mosquito range on the west. Some of these strata even cap the top of the highest mountains of Colorado, such as Silverheels and Mt. Lincoln. The former with red Trassic sandstone, the latter, over 14,000 feet high, with Carboniferous limestone. Thus part of what was once the floor of the park by upheaval along its edges has become the summit of its encircling range, and what was once the bottom of a primeval sea with its entombed sea shells has been elevated to the top of the highest mountains, and the whole strata of the park itself have been raised bodily 4,000 feet above the position of the same strata, belonging to the same time of formation on the great plains, for the average altitude of the South Park is 10,000 feet above the sea level, while that of the plains is between 5,000 and 6,000. It is thus a fragment of the great plains and prairie caught up is the embrace of the rising mountains and lifted bodily to a height of 5,000 feet above them.

The geological history of the North, Middle and South parks is briefly that they were submerged in Paleozoic and Mesozoic times by the sea and at a later period, viz: in Tertiary times by fresh water lakes. They formed a connected series of bays and arms of the sea and afterwards of fresh water lakes as shown by the succession of marine and fresh water sediments found in them.



"In Paleozoic times the outlet of the sea of the North Park was towards the north, of the Middle Park toward the west, and of the South Park toward the south. Up to the close of the Cretaceous, the North and Middle parks were connected forming a single depression. The present mountain barrier between the Middle and South parks did not extend as far as their western boundaries and a water connection lay between them." Proof of this we find in narrow patches of sedimentary rock lying along the valley of the Blue river beyond Breckenridge which connects the parks together.

The waters of the South Park in Paleozoic times extended westward to the flanks of the Sawatch range, the present intervening Mosquito range not then existing, it having been lifted up later in the Cretaceous. In Tertiary times the peaks had been raised sufficiently above the ocean level to be occupied by great fresh water lakes bounded on the west by two ridges or islands parallel with the Front range, viz: the Park range proper on the west side of North Park, and the Sawatch range now separated from the South Park by the Mosquito range but practically a continuation of the Park range, while between the Sawatch and Park ranges lay the granitic Gore range forming with portions of the Park range the western wall of Middle Park.

In the period intervening between the close of the Cretaceous and the laying down of the Tertiary strata during which the waters of the ocean were gradually receding from the Rocky Mountain region and permitting coal beds to form in marshes from peat and land vegetation, the pent up forces of contraction in the earth's crust which had long been accumulating, found expression in dynamic movements of the rocky strata, pushing together from the east and west the more recent stratified rocks against the relatively more rigid masses of the Archean granitic land and thus folding and crumpling the beds in the vicinity of the shore lines. So were these shore line strata crumpled up to form the Mosquito range, constituting the present western boundary of South Park.

These ranges were not uplifted by an up-thrust from below, but by horizontal tangential pressure resulting from contraction of the earth's crust caused by the cooling of its interior. This is



shown in the folded character of the rocky masses and as the forces of contraction became stronger, the folds were pressed closer together and finally broken in enormous fractures or faults in lines parallel to the trend of the range and the axes of the folds. Eruptive rocks poured out in many places through the fissures so formed and added to the mountain masses. Along the line of the Parks both earlier and later eruptions are so frequent as to form nearly a continuous belt.

The structure of the Mosquito range is a typical one. It consists of a series of gigantic compressed folds of the strata of South Park, containing numerous intrusive sheets of eruptive rock intercalated between the beds. The whole mass is repeatedly fractured by a series of faults running parallel with the trend of the range, and the axes of former folds.

Its history is briefly as follows:

In the seas of the Paleozoic and Mesozoic eras that beat against the Sawatch island, 10,000 feet of sandstones, limestones, conglomerates and shales were deposited. Towards the close of the Cretaceous, or perhaps earlier, eruptions occurred beneath the sea bottom by which enormous masses and sheets of eruptive rock were intruded through the Archean floor into the overlying sedimentary beds that still lay beneath the waters, crossing some of the beds and spreading out in immense intrusive sheets but never reaching the surface. The great uplift followed, crumpling up and faulting the strata with their included sheets of eruptive rock and raising them into the lofty range called the Mosquito.

The South Park branch of the Union Pacific railroad enters the park on its northeastern corner and in its course passes through a partial section of the Park strata. As the train descends from the granite of the Colorado range into the park we find the first portion for some miles horizontal and covered with glacial drift, below which probably lies an indefinite thickness of Tertiary or else upper Laramie beds underlaid by the lower Laramie or coal bearing group. The latter as we reach Como station becomes upturned into a hogback against a heavy mass of eruptive rock lying to the west of it and forming the steep hill back of the town of Como. The outcrop of the coal bearing series can however at



intervals be followed in a crescentic line disturbed by dykes and faults from Como at the north to within a few miles of the Midland railroad, which enters the park near its southeast corner. This outcrop makes a bend a few miles south of Como, round a promontory of granite issuing from the Colorado range and known as Lost Park. Some of the coal openings are situated close to Como and others nearer the bend of this promontory in a line of about six miles.

Beyond that point there are no important openings, though traces of coal have been found as far south as a few miles northeast of Hartzell's Hot Springs. The borings made there found the coal seam too narrow to work and disturbed by faultings and the presence of eruptive dykes. These disturbances seem to be the prevailing character in developing the coal of the park along its outcrop, but it is probable that the coal would be found less disturbed and more horizontal at some point east of the present line of development if borings should find it within accessible depth from the surface. The Laramie group can generally be traced in this section without much difficulty by the presence of fossil leaves, which are abundant. West of the coal outcrop is generally a flat valley belonging to the Colorado and Foxhills groups of the marine Cretaceous, in which, of course, no coal is to be expected. Through the centre of these groups, whose thickness is several thousand feet, runs an enormous dyke of eruptive rock of a pink or grey porphyritic lava, showing occasionally a brecciated character. This thick dyke, half a mile to a mile in breadth, forms a lofty ridge running north and south the greater length of the park, constituting the east bank of Trout creek, the opposite timbered bank being a hogback of the Dakota Cretaceous sandstones. In the bottom of the valley, along Trout creek, fossil marine Cretaceous shells, such as inoceram, baculites, scaphites and ammonites are common.

At Garo station we pass through the second prominent ridge of the Park formed by the Dakota sandstone dipping east  $45^{\circ}$  and find ourselves in another valley occupied by the Platte river. This valley is underlaid by the variegated shales and red sandstones of the Triassic period, whose brilliant red hues stain the banks on the west



side of the stream. The Triassic sandstones are traversed by a few thin belts of dark gray or blackish limestone, in which, however, no fossils have so far been found. A few miles south of Fairplay, along the banks of the Platte, among the red strata is a curious local outburst of Trachytic tufa cut by erosion into rounded forms like a flock of sheep. This patch, from its white color can be easily seen from the railroad between Fairplay and Garo. Not far from this we found some years ago in a series of shales numerous impressions of leaves and fossil insects. The latter have been identified by Professor Scudder, and some of them shown to belong to the cockroach family, the earliest discovery known of this order. The discovery was made in prospecting and boring for some thin coal seams which outcropped near the surface. The latter proved valueless, but the insect discovery was a notable one for science, and led to a controversy not yet decided, as to whether the lower part of these red beds are Triassic or Permian.

From this west bank of the Platte a broad flat plateau extends to the foot of the Mosquito range underlaid by tilted rocks of the Upper Carboniferous consisting of brown-red conglomerates near the top, and near the base a thick series of shales in which occasionally obscure traces of coal and carbonaceous shales can be found which have so far proved unproductive. We may here say that experience shows that as no coal of importance is to be looked for either here or generally in Colorado below the Laramie group the coal area is restricted to that portion of the park lying east of the coal outcrop from Como to Hartzell's Hot Springs.

We must leave the train now and enter the Mosquito range by Four Mile or Horseshoe cañon where the structure of this range is better shown in section than anywhere else in the park. We find the first uplifted set of strata forming the west slope of the range to be made of gritty conglomerates and quartzites known as the "Weber grit" series belonging to the Middle Carboniferous. Underneath these comes a thick belt of dolomitic limestone belonging to the Lower Carboniferous so productive of silver and lead ores, and below this again several hundred feet of shales and hard vitreous white quartzites belonging to the Silu-



rian and Cambrian epochs. The latter rests on the upturned granite which appears in the bottom of the cañon. Intercalated between these various beds are many intrusive sheets of white and gray porphyry, and as we go up the creek we notice dykes from which these sheets branched, traversing the strata, and towards the head of the cañon leading up to enormous laccolitic intrusive masses which by removal of the strata that once arched over them, now constitute hoary peaks of volcanic rock. But by far the most striking feature in the cañon is evidence of dynamic force in the structural position of the strata. On entering we see a perfect steep arch as of masonry constituting Sheep mountain an illustration of which is given in our "Geology of Colorado ore deposits." This first great and steep fold is followed by a sharp depression, and a series of abrupt step-like outlines which continue until we emerge on the other side of the range and look down into the broad valley of the Arkansas, where step follows step till they finally pass under the drift-covered surface of the valley. The depressions and the steps or notches in the mountain outline mark a series of faults each one corresponding to a fold like that still remaining on Sheep mountain. We see that as the pressure from the Park side i. e. the east crumpled the strata against the great unyielding mass and shore line of the Sawatch range whose majestic peaks appear across the valley of the Arkansas on the west, the tension became very great and the folds broke into a series of step faults some of them having a slip of several thousand feet.

A few spirifers and other shells are to be found in the lower Carboniferous rocks in this cañon and in the Weber shales some impressions of *Lepidodendra* and other Carboniferous vegetation. The part traversed by the Midland railway toward the southern part of the park is principally through marine Cretaceous beds of the Fox hills and Colorado Cretaceous shales traversed by dykes of eruptive rock. Sulphur springs issue from these, and at Hartzells are hot springs issuing from the Dakota rocks, beyond this the road traverses the Jura-Trias red beds, from which at the old salt works issue springs sufficiently saline to produce by evaporation commercial salt; gypsum too is abundant. All the southern part of the park is covered by eruptive



rock, such as rhyolite and dolerite. Buffalo peak, a prominent castle in the Mosquito range, is formed of a great eruption of Andesite lava in columnar form, belonging to the later series of eruptions dating from the Tertiary period. The mountains surrounding the park show in their sculpture the work of former glaciers, and the surface of the park is strewn with boulders brought down by them from the adjacent hills.

#### THE COAL MINES.

The coal mines in the Park are all located within a short distance of the town of Como, and are mostly operated by the Union Coal Company. The Como No. 1 mine is opened by a slope 800 feet deep driven on the dip of the seam which pitches  $45^{\circ}$  in an easterly direction, levels are driven north and south from the slope at intervals of 100 feet. The rooms are worked on the dip the coal being run into chutes from which it is loaded on cars in the main levels. The width of the seam is seven feet. In 1885 the mine produced 58,997 tons.

"Como No. 4 mine" was operated in 1882, but before long one of the many faults that trouble this field was encountered, and the coal was lost, nor was it found again by boring, hence the mine was abandoned. A similar experience, according to Mr. McNeil, was met with by the Denver & Rio Grande Co., a mile northwest of Como, where not only were faults and obstructions met with, but a coking plant costing \$80,000 had to be abandoned as well as the mine, because the coal failed to make good coke. A new mine called "Como No. 5" has been opened of late, which shows a seam seven feet thick of good coal. The capacity of this mine is about 200 tons daily.

If the reader could have accompanied us in our trips he would have travelled over the greater part of the mountain region of Colorado, would have seen some of the grandest of its scenery, and while investigating the principal developed coal fields, he would at the same time have seen the most interesting and leading features of Colorado geology which we have sometimes gone out of our way a little to describe, endeavoring to combine a sketch of our coal fields with one of the general geology of the state.



## CHAPTER XIII.

### Colorado Cokes.







## Chapter XIII.

### COLORADO COKES.

BY PROFESSOR B. SADTLER, JR.

COLORADO STATE SCHOOL OF MINES.

A chapter on Colorado Cokes had best commence, like its title, geographically. On the eastern side of the Continental Divide rather a small proportion of the enormous acreage of coal lands contains coking coal. At Trinidad, south and west, and to some extent north of it, the coal is strongly coking. As we go along the narrow strip of post-Cretaceous reaching northwest to the Huerfano river, the coking quality gradually disappears, through the different stages of sintering until at the northern extremity of the field the coal is all free burning. No exact locality can be named as the dividing line between the coking and the non-coking coals, but a point east of the Spanish Peaks, between the Apishapa and Santa Clara creeks would mark the northern limit of at least a preponderance of coking coal veins. I believe that an abortive attempt to coke the South Park coal in the neighborhood of Como was also made. On the western side of the divide coking coals are mined and coked near Durango, and large veins exist south, west and, to some extent, east of this point. North, in the valley of the Gunnison, coal has for a long time been mined and coked at and near Crested Butte.

Still further north, in the valley of the Grand river, coke is burned at a number of points reached by the Denver & Rio Grande and Colorado Midland railways. While coal, presumably coking, exists over large undeveloped areas in the northwestern portion of the State, it has not been mined or shipped in sufficient quantities to render data, as to coking obtainable. The coals of eastern Colorado are all post-Cretaceous and have been, on that account, erroneously classed by many writers as lignites. While this is generally true as regards the coal north of the Arkansas



river, it is not only untrue, but does gross injustice to the strong, free burning coal of the Cañon City district, and the semi-bituminous, sintering and coking coals of Walsenburg, Trinidad and neighboring points. These are far more nearly allied in their composition and economic value to the Pennsylvania Bituminous coals than they are to the northern Colorado Lignite. While a number of theories have been advanced as to the cause of the coking power in coal, the writer inclines to the following as in his opinion, best substantiated by facts. That is, briefly, that it depends upon the amount of bitumen present. This, when exposed to the heat of the coking process melts and boils as its more volatile constituents are expelled, leaving among the portions of woody fibre a solid carbon residue which cements them together. In the case of a sintering coal the proportion of bitumen would be insufficient, making the resultant coke friable.

Although the fixed carbon in a coking coal is generally higher, and the "volatile combustible" lower, this is not a safe index, as the percentage of these two constituents (though rarely) may be identical in two coals, and the coking property widely different. This could be attributed to the fact of the "volatile combustible" being in one case more largely made up of gas or readily volatile hydro-carbons and the bitumen present in smaller proportion. In weathering, coal will frequently lose the coking property, which is probably due to the decomposition of some of the oily constituents, hence no test of the coking property is final unless the coal is sufficiently removed from surface influences to be unweathered. A convenient method of making the tests is by placing a common assay crucible with 10 or 20 grammes of the powdered coal, and tightly covered, (a well fitted scorifier makes a good cover), in a hot muffle and keeping it there until luminous flames cease to appear. If there is no muffle convenient the crucible may be placed in the midst of coals in a hot stove. Allow the crucible to cool after removing from the muffle before taking off the lid. If the contents show no sign of the shape of the original particles, are strongly coherent and on breaking open show evidence of ebullition, the coal may be safely considered as coking. If the shape of the original particles remains and the mass is friable, the coal is only sinter-



ing. In case of any doubt and also in order to determine the power of the coke to withstand a crushing burden, the coking of a heap of coal would be advisable (see directions for "burning of coke in heaps" in Manuals) rather than risk the useless erection of costly coke ovens, as is said to have been the case at Como, in this State, where \$80,000 was expended for a coking plant before the coke was found to be so friable as to be useless, the coal being only a sintering coal.

Where a large number of coking tests, or even coal analyses are to be made, and an assay muffle is at hand, I have found that a large number of fixed carbon, volatile combustible and ash determinations could be made simultaneously by using an assay crucible for a 10 or 20 gramme charge of coal and placing in the tightly fitting scorifier lid one gramme of powdered coal for ash determination. Place in a hot muffle until luminous flames cease to appear, then remove until it has cooled somewhat, when the scorifier can be replaced in the muffle if not sufficiently burned. The larger quantities used, if the scorifier lid fits neatly so as to exclude air, render the loss of fixed carbon small.

Prof. Geo. C. Tilden has checked this method frequently against the ordinary way of using a platinum crucible, and tells me that he gets uniformly somewhat higher results in fixed carbon than in the ordinary method. As, however, it checks itself very well I should consider it fully as accurate.

As the amount and composition of the ash in a coke is of the first importance, I have in all cases given analyses of smelter sample of large lots; grab samples frequently varying so much as to be worthless. It is, however, often desirable to form an idea of what a coke will run in ash prior to its manufacture. When all of the coal from the vein, and not merely the slack, is used in coking burning an approximation may be obtained as follows:

Take an average sample across the vein and quarter it down as in ore sampling. Analyze sample, and deduct ten per cent. from the total of ash and fixed carbon found. This will give about the net percentage yield of coke. Divide this into the percentage of ash found in the coal sample and the result will be the probable average ash in the coke. An example may be useful. Taking the analysis of an average sample of coking coal as 54



per cent. fixed carbon and 11 per cent. of ash, this gives a total of 65 per cent. as the theoretical amount of coke. Assuming the net practical yield to be 10 per cent. less, or 55 per cent., the coke would contain 20 per cent. of ash, *i. e.*  $\frac{11 \times 100}{55} = 20$ . Comparing Prof. Tilden's analyses of average samples of coal and the smelter averages on coke from the same coals, we find that this will generally give a fair approximation.

The ingredients bearing upon the commercial value of coke, are the water, sulphur, volatile combustible, ash and fixed carbon. Of these, the latter only is valuable, the first four being to a greater or less extent detrimental, should be as low as possible in good coke.

The water is present only in large quantity when careless or ignorant workmen have used it too freely in the quenching of the coke.

We can, however, afford to leave it out of our calculations in the Colorado cokes, as from a large number of analyses at hand, the great majority show less than 1 per cent. of water. The few cases where it exceeds this amount are from new plants and doubtless attributable to the inexperience of the workmen, which time would remedy. If water were present in large quantity it would materially lessen the heating power of the coke.

The volatile combustible would, if present in at all large quantity, cause the coke to shatter in a blast furnace. For this reason gas-cokes are not used in such work; the bitumen being not entirely driven off in the retorts. This point we can also afford to disregard as in none of the analyses at hand is it present in dangerously large amounts. The few containing an appreciable quantity are, as above stated, from new works.

The sulphur in coke occurs mainly when iron pyrites is present with the coal, and its presence is probable when analysis or color of the ash shows an unusually large percentage of iron. While detrimental in iron smelting, it is not present in sufficient quantity to make much difference in lead-silver or copper-silver smelting; the highest determination given me of any Colorado cokes being 1.35 per cent. In fact, most Colorado cokes are quite low enough in sulphur for use in iron smelting.

The constituent which cuts a real and considerable figure in



all Colorado cokes, is the ash, which is with few exceptions high. When the ash of a coal or coke is only such as would result from the condensation of the plant ash of the coal-bearing flora, it should rarely exceed 6 per cent. in the coal or 10 per cent. in the coke. A lower ash than this is called normal, and is in metallurgical work considered as self-fluxing.

When the ash exceeds these figures it is generally siliceous and may result from a failure to sort out the slate cleanly, or from what is known as "bone" in the coal which is supposed to be caused by a washing in of sand or a mixture of sand and clay with the coal at the time of its deposition, and is so incorporated with the coal as to make its hand-sorting impossible. Even washing and concentrating the coal slack has proved at times insufficient to separate it. This sand and clay is of course highly siliceous and its presence in a coke makes it far less desirable to the smelters than a coke with a normal or self-fluxing ash. An example may make this clearer. Taking a normal coke with ash at nine per cent. as a standard; a coke with nineteen per cent. ash would have the excess of ten per cent. mainly made up of sand (or silica) and clay (or silicate of alumina). As ore of this class, which it replaces in the furnace, has to be heavily fluxed and would be given about a fifteen dollar smelting charge, we can readily see that the ten per cent. excess of ash would cost the lead-silver smelters of this State about one dollar and a half per ton of coke, in addition to the fact they are paying for ten per cent. of dead weight instead of fuel. The furnaces would also work poorly with such a coke. The fine broken coke found near the bottom of all large stock piles has been noticed to run especially high in ash and silica. Cases have come under the writer's observation in which this fine material forms a very large proportion of furnace crust or barrings and one case in which the careless use of too much fine coke directly caused the crusting or hanging. The high ash in coke may also be largely due to the presence of iron oxide from the burning of the iron pyrites present in the coal. This helps to flux the silica present and is to that extent beneficial, although rarely present in sufficient quantity to make much difference.

I append analyses of the different cokes at present sold in the



State. Through the kindness of my friends in the business, which I acknowledge more properly below, I have been able to obtain the smelter average of the different cokes. In consequence the analyses give the average of an aggregate of several thousand tons; the figures being averages of analyses of samples of as high as fifteen lots of two or three hundred tons each. Nearly forty lots and over sixty analyses are represented in the figures given, which have been condensed in order to give the information in as concise a form as possible.

We shall first take up the Trinidad coking coal fields as being the oldest and largest producers. In El Moro coke the water is invariably low, under 0.5 per cent. The volatile matter is also low, averaging under 1 per cent. The fixed carbon runs from 76.6 per cent. to 80.3 per cent. with an average of 79.1 per cent. in six determinations. The ash in twelve determinations of coarse coke averaged 18.7 per cent., the highest being 22.3 per cent., the lowest 16.5 per cent. The silica in the ash showed an average of 67 per cent. ranging between 65.2 per cent. and 68.5 per cent. The iron in the ash showed an average of 7.6 per cent. varying between 6 per cent. and 8.5 per cent. The reducing power, determined by Berthier's method, gave an average of 24.12 grammes of lead or 71 per cent. as compared with pure carbon. This method has been proved by investigation to give results constantly about one-ninth below the theoretical reducing power, so the above statement may be accepted as conservative. Some analyses of the remaining constituents of the ash gave 21 per cent. of alumina and 1.5 per cent. of lime. This would indicate either that the coal had not been thoroughly cleaned from slate, or that clay, as well as sand, was a constituent of the "bone." The former case would seem more probable. The coke from Starkville and other points in this region shows the same peculiarity, high and siliceous ash. The average of a large number of lots, of which the writer had personal knowledge, was 20.5 per cent. ranging between 17.5 per cent. and 24 per cent. This peculiarity of the coking coals of this district led to an attempt to free the slack from slate and "bone" by washing before coking, as is successfully done in some foreign districts. The effort was not continued, whether because too costly or



because the impurity was too thoroughly incorporated in the coal as "bone;" the writer has heard the latter cause assigned. The parts of coke having an especially high ash seem most friable, as we find that the fine or broken coke has a markedly higher and more siliceous ash. An analysis of a sample of fine El Moro coke gave 26 per cent. ash which contained 70.33 per cent. of silica and 5 per cent. of iron.

The Trinidad coals, with the exception of the high ash, which nearly all Rocky Mountain coking coals yet discovered show, are good, coking readily and making a strong, coherent product, which finds a good market in Pueblo, Denver, Leadville and elsewhere.

We shall next consider the Durango coke, necessarily briefly, as the coke is only locally used and data consequently scant. The San Juan smelter gives an average of 11 per cent. ash for the coke from the Porter mine, and 13 per cent. ash for that of the San Juan mine. As these figures are not much in excess of those taken as normal or self-fluxing, and the coal analyses given in Prof. Lake's report, give equally good results, we may safely assume that distance from a larger market alone restricts the production.

The Crested Butte coke shows a large variation which, however, is, to some extent, regular and chronological. A number of data show that, up to within about two years, the ash was extremely low, running only four to five per cent., and of course self-fluxing.

About the winter of 1887 and 1888 its character began to change, the ash becoming higher, until at present it ranges in averages from 8 per cent. to 13 per cent., although some grab samples went as high as 17 per cent. A recent average analysis is as follows: Water 0.32 per cent., volatile matter 0.49 per cent., fixed carbon 87.02 per cent., ash 12.17 per cent., the reducing power 76.65 per cent. The ash was somewhat siliceous, having 44.2 per cent. silica, 16.43 per cent. iron, the remainder being made up of other bases. Samples with lower ash are self-fluxing or basic. This coke is not so strongly coherent as that from Trinidad, but still is good. It is largely marketed in Gunnison and Utah smelting points.



The Grand river coking coal fields, although but recently opened, are making a strong bid for public favor. Although the writer has over twenty analyses of cokes from this district, most of them on large lots, the exact locality could not in most cases be obtained. The first lot was labelled "Colo. Midland." In fifteen analyses the water was mostly under 1 per cent. and in one case only, over 2 per cent. The volatile combustible was always under two per cent. and in most cases under one per cent., the fixed carbon ran from 79.76 per cent. to 88.58 per cent. with an average of 83.78 per cent. The ash ran from 10.1 per cent. to 19.1 per cent. with an average of 14 per cent. The silica in the ash ran from 45 per cent. to 54 per cent. with an average of 50.6 per cent. The iron ran from 7.33 per cent. to 14.95 per cent. with an average of 10.6 per cent.

A sample of fine coke showed the same high silica in the ash as mentioned above, the amount being 74 per cent., which is notably higher than in any of the coarse samples.

The average reducing power of these cokes as compared with carbon was 75.75 per cent.

Another batch of analyses which were called "Grand River coke" are on samples taken when the coke was suspected of being below the average quality. They had an average ash of 15 per cent., ranging between 13.4 per cent. and 16.8 per cent.

The silica in the ash ran from 50.3 per cent. to 60.4 per cent. with an average of 56.6 per cent. The iron varied between 14.4 per cent. and 16.5 per cent., with an average of 15.2 per cent.

An average lot of the Marion coke gave 9.6 per cent. ash, which contained 35.4 per cent. silica, and 21.14 per cent. iron. This, allowing the difference to other bases would be nearly or quite self-fluxing. The higher amount of iron in the Grand river cokes would make the ash more nearly self-fluxing and would also indicate the probable presence of some residual sulphur from the burning of the iron pyrites in the coal. Two tests for this gave respectively 1.35 per cent. and 0.947 per cent. sulphur.

It might be well to state, for purposes of comparison, that Connelsville, Pa., coke runs about 11 per cent. ash, and Alabama coke 13 per cent., although the data obtained are a little scant. Many English and foreign cokes run as low as 5 per cent. ash,



which is due at times to the purity of coal and care in sorting out slate and at other times to mechanical preparation and the washing of the slack. While the high price of labor would render the same degree of preparation unprofitable in this country, still, if a suggestion is allowable, it would be to exercise the maximum degree of care in keeping the slaty and other impurities out of the coking coal. The smelters do not want to smelt more clay and sand gratis than they have to, and the purest product should and will command a premium.

It would be ungrateful in the writer to close this article without acknowledging his indebtedness to the following gentlemen: Messrs. Edwin N. and J. Dawson Hawkins, chemists of the Globe Smelter, Denver; Mr. R. C. Canby, Superintendent of the Arkansas Valley Smelter, Leadville; Mr. P. S. Morse, Superintendent of the Germania Smelter, Salt Lake, Utah; Mr. E. J. H. Amy, Assistant Manager, San Juan Smelter, Durango, and others.

Their kindness in furnishing data has enabled him to give reliable averages from large lots, instead of analyses of "grab" samples which would be necessarily inaccurate and often misleading.







## Appendix.







## Appendix.

### AGE OF THE ARAPAHOE AND DENVER BEDS

#### AND DISCOVERY OF A GIGANTIC FOSSIL "HORNED TOAD."

We have assumed in this report that the Denver and Arapahoe beds of the Denver basin are of Tertiary age on the authority of the recent reports of the U. S. geological survey, but not because we think their age thereby proved beyond a doubt. It is still a question whether they are not after all upper local subdivisions of the Laramie Cretaceous. The recent discoveries of extraordinary Dinosaur remains in these beds and in the Laramie group favor the latter view, otherwise these discoveries would drive us to the conclusion that these great saurians lived on beyond the Cretaceous into the Tertiary period, a point which paleozoologists would be slow to admit.

Since we began this report Prof. Marsh's party has discovered some remarkable Dinosaur remains in these beds and those of the Laramie, called the *Ceratopsidæ*, or horned-faced saurians. So numerous are these remains at different points in the Upper Cretaceous along the eastern flank of the Rocky Mountains in Montana, Wyoming and Colorado that Professor Marsh has named the horizon in which they occur, the "*Ceratops beds*." He says, "The beds in which these bones are common are in the Upper Cretaceous. They are fresh-water or brackish deposits which form part of the so-called Laramie group, but are below the uppermost beds referred to that group. In some places they rest upon marine beds which contain invertebrate fossils, characteristic of the Fox-Hills deposits. The fossils associated with the *Ceratopsidæ* are mainly Dinosaurs, representing two or three orders and several families. Plesiosaurs, crocodiles and turtles of Cretaceous types, and many smaller reptiles, have left their remains in the same deposits. Numerous small mammals also of ancient types, a few birds and many fishes are likewise



entombed in this formation. Invertebrate fossils and plants are not uncommon in the same horizon."

Some remarkably perfect skulls of a species of these gigantic Dinosaurs called Triceratops, or three-horned faced Dinosaur, were recently discovered in Wyoming by Mr. T. B. Hatcher. Professor Marsh says, "that the skull exceeds in size that of any land animal extinct or living and is only surpassed by that of the Cetaceans or whales." The skull is over eight feet in length. The mouth was armed with a sharp cutting beak like that of a snapping turtle. There was also a strong horn on the bridge of the nose and a pair of very large pointed horns on the forehead, each two feet six inches in length. (It was the discovery of fragments of these horns by Messrs. Eldridge and Cannon in beds in the Denver basin, supposed to be of Tertiary age, that led them at first to be considered as belonging to the great extinct buffalo—Bison Alticornis). As if such extraordinary armature was not sufficient, there was a row of sharp projections around the back of the head, like a mastiff's spiked collar. "For offense or defense they formed together an armor for the head as complete as any known. This armature dominated the skull, and in a great measure determined its form and structure." The skull itself is wedge-shaped in form, being very broad and massive toward the forehead and back, to support the heavy armature, and tapering toward the snout. The teeth were comparatively small and crenated, resembling those of the ancient Hadrosaurus or the modern Iguana, and show by their structure that the animal was of herbivorous habits, and probably inoffensive, relying upon his extraordinary defensive armature for protection against the onslaughts of the terrible carnivorous Dinosaurs.

The modern living creature that this extraordinary monster most resembled is the little horned lizard (*Phrynosoma*), commonly called a "horned toad," often found on our Colorado prairies. The size of the monster Prof. Marsh has not yet told us, but, judging from its enormous head, it must have been truly gigantic.

If we can picture to our imagination a "horned toad" of more than elephantine proportions, bristling with horns and



spikes, with a huge head, armed on the forehead with two long, sharp horns, greater than those of the long-horned rhinoceros, and a smaller horn on the nose, we may form some conception of the monster that roamed among the palmettos and ferns that clothed the marshes of our coal period in Colorado, or plunged into the lakes around which that beautiful tropical vegetation grew—vegetation now either preserved in fossil imprints or turned into coal. The discovery of perfect skulls of these Dinosaurs in Wyoming throws much light upon the few scattered saurian remains that have been found from time to time in the leaf beds of the Table Mountains at Golden and similar strata under Denver. Doubtless these bones belong to the same species, or to genera of Dinosaurs allied to them.

### COAL PRODUCTION.

[By Hon. John McNeil, State Inspector of Coal Mines.]

The following is a summary of the coal statistics of the State for a number of years:

<i>Years.</i>	<i>Tons.</i>
1873 . . . . .	69,977
1874 . . . . .	87,372
1875 . . . . .	98,838
1876 . . . . .	117,666
1877 . . . . .	160,000
1878 . . . . .	200,630
1879 . . . . .	322,732
1880 . . . . .	375,000
1881 . . . . .	706,744
1882 . . . . .	1,061,479
1883 . . . . .	1,220,593
1884 . . . . .	1,130,024
1885 . . . . .	1,398,796
1886 . . . . .	1,436,211
1887 . . . . .	1,791,735
1888 . . . . .	2,185,477
1889 . . . . .	2,373,954



Production of coal for year 1887, by counties, is as follows

<i>Counties.</i>	<i>Tons.</i>
Las Animas (including coal made into coke)...	506,540
Fremont.....	417,326
Boulder.....	297,338
Gunnison (including coal made into coke)....	243,122
Huerfano .....	131,810
Weld .....	39,281
El Paso.....	47,517
Garfield (including coal made into coke).....	26,000
Pitkin.....	4,000
La Plata (including coal made into coke).....	22,880
Park.....	23,421
Arapahoe .....	16,000
Jefferson.. ..	12,000
Douglas.....	3,500
Dolores.....	1,000

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Total.....1,791,735

For the year ending December 31, 1888, the returns of the coal production made to this office, and estimates made for latter part of December, are 2,185,477 tons, of 2,000 pounds. Of the above amount, 700,547 tons, or a little over 32 per cent. of the State's production, have been shipped outside the State to points in Kansas, Texas and Nebraska.

Production by counties is as follows:

Las Animas (including coal for coke).....	706,455
Fremont.....	438,789
Boulder.....	315,155
Gunnison (including coal for coke).....	258,374
Huerfano.....	159,610
Garfield.....	115,000
La Plata (including coal for coke).....	33,625
Pitkin (including coal for coke).....	28,113
Weld.....	28,054
El Paso.....	44,114
Jefferson.....	9,000
Arapahoe.....	1,700
Park.....	46,588
Douglas.....	400
Mesa.....	300
Dolores.....	200

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Total.....2,185,477



Production by counties for the year ending December, 21st, 1889, showing increase and decrease over and from figures of 1888. The month of December is partly estimated:

<i>Counties.</i>	<i>Tons (2,000.)</i>	<i>Incr'se.</i>	<i>Decr'se.</i>
Arapahoe.. .. .	900.....	.....	600
Boulder..... .	297,703.....	.....	17,362
Douglas..... .	300.....	.....	100
Dolores..... ..	none .....	.....	200
El Paso..... ..	54,066.....	9,952.....	
Fremont... .. .	279,855 .....	.....	158,943
Gunnison..... ..	251,808.....	.....	6,566
Garfield..... ..	144,627.....	29,627.....	
Huerfano.. .. .	309,023.....	149,413.....	
Jefferson..... ..	6,600.....	.....	2,400
Las Animas.....	876,990.....	170,535.....	
La Plata..... ..	32,630.....	.....	995
Mesa..... .. .	none .....	.....	300
Park..... .. .	47,005.....	417.....	
Pitkin..... .. .	46,181.....	18,068.....	
Weld..... .. .	26,176.....	.....	1,878

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2,373,954

Output for 1888, 2,185,477; Output for 1889, 2,373,954, being an increase over 1888 of 188,477 tons.

The average value of coal on the cars at the mines is \$2.20 per ton, making the value of the State's production in 1888 \$4,808,049.40. The average number of persons employed is 5,375. The average thickness of the coal seams now being worked through out the State is 5 feet 5 inches; the thickest is 45 feet, and the thinnest, 1 foot 8 inches. The average price paid to miners for digging and loading the coal and timbering the working places is 70 1-5 cents per ton of 2,000 pounds of screened coal, average screen being about 1¼ inches between bars. The average cost of producing the coal on the cars at the mines, including royalty, is about \$1.80.



## VARIETIES OF COAL

AND WHAT QUALITIES AND PROPERTIES DISTINGUISH GOOD COAL  
FROM INFERIOR. LE CONTE'S GEOLOGY.

"Varieties of coal depend on purity, degree of bituminization, proportion of fixed and volatile matter.

Coal consists partly of organic or combustible, and partly of inorganic or incombustible matter.

On burning coal the organic combustible matter is consumed and passes away in the form of gas, while the inorganic incombustible is left as ash. The relative proportion of these may vary to any extent. We may have a coal of only 2 per cent. ash, or one of 5, 10, 15, 20 per cent. ash, the coal is now becoming poor. A coal of 30 or 40 per cent. ash is bony or shaly coal and valueless. When it reaches 50 or 60 per cent. ash it is merely a coaly shale from which it passes into the blackened or ordinary shale of the roof of a coal mine.

All vegetable tissue contains incombustible matter which is left in burning as ash. The amount of ash in vegetable matter is about 1 to 2 per cent. If a coal contains 5 per cent. or less of ash it is considered as absolutely pure, *i. e.* its ash comes wholly from the vegetable tissues of which it is formed, but if a coal contains 10 per cent. or more it is impure, having been mixed with mud at the time of its formation and accumulation.

Vegetable matter accumulated in different geological periods, is in different stages of that peculiar change called bituminization; brown coal and lignite are examples of such imperfect coal and are comparatively modern.

Coal even when pure and perfectly bituminized consists of different varieties having different uses, depending upon the proportion of fixed and volatile matters.

In pure, perfect coal the combustible matter is part fixed, part volatile. These may be separated by heating to a redness in a retort. The volatile matter is thus driven off and may be collected as oil or tar in condensers, and as permanent gas in gasometers; the fixed matter is left in the retort as coke. The pro-



portion of these varies in different coals and affects the uses to which coal is applied. If the coal is wholly fixed carbon it is graphite or black lead and nearly incombustible; not used as coal, but as a lubricator of engines, for lead pencils, crucibles, etc. It is coal, but the last term of the coal series.

When the combustible matter contains 90 or 95 per cent. fixed carbon, it is called anthracite, burning with no flame and producing much heat. It is an excellent domestic coal and with hot blast may be used in smelting furnaces.

If the combustible matter contains 80 to 85 per cent. fixed carbon and 15 to 20 per cent. volatile matter, it is semi-anthracite or semi-bituminous coal. This is free burning, producing long flame and high temperature, and does not coke or clog. This is especially good for rapid production of steam for locomotives. If the volatile combustible matter rises to 30 or 40 per cent., it becomes full bituminous coal, burning with a strong, bright flame, after coking and forming clinkers. This is one of the commonest kinds of coal.

If the volatile matter is about 50 per cent. it is highly bituminous, or fat fusing coal, adapted to the manufacture of gas and coke.

In a general way we estimate the ordinary quality of coal mainly by its high or low per cent. of fixed carbon or amount of ash."

Some other properties are also to be considered, viz: Whether the coal slacks or not on exposure to the atmosphere. This is a cause of great waste in the coal bin and in slacking in the coal yards, and is more characteristic of the lignitic coals of our northeastern area, owing to their high per cent. of water contained, than of the majority of coals from the west of Colorado. Another quality is the fracture of the coal. It is a good point for the coal to break in large, solid, square blocks. Some coal when struck with a pick or hammer flies into small coal, almost as wasteful as the slacking coal. Coal in Colorado is rarely good till a certain depth has been gained below the surface.

In estimating the comparative values of coals from analyses the following points should be borne in mind. The sulphur in



coals used for gas making produces certain poisonous and injurious gases, which impair the quality of the resultant illuminating gas. In a coking coal the quality of the coke will be impaired (see chapter on coke). The water, which occurs in large percentage in all lignite coals, is not only dead weight, but directly lessens the heating effect of the volatile combustible matter and fixed carbon present. Care should be taken in sampling lump lignite coals to determine the water very promptly after the lumps are broken up as the water dries out of the coal very quickly when powdered, and the results would be so low as to unduly favor the lignite. Coal slack of this class shows, on account of this cause, a uniformly lower percentage of water than the lump coal.

The ash in a coal is dead weight, and in coking coals has other bad effects mentioned under that head.

The valuable constituents of all coals are the fixed carbon and volatile combustible. Bituminous coals, high in fixed carbon, are mostly coking. A general rule may be made that the higher the percentage of fixed carbon in a coal the greater the proportion of its heating effect which may be practically utilized. The volatile combustible matter in a coal, when high, makes a coal especially valuable for gas making and for metallurgical and other operations in which a long flame is required, as for example ore roasting. For steam making and ordinary heating purposes a considerable portion of the volatile combustible is wasted in a thick black smoke, unless smoke consumers are practicable and are used.

Through the kindness of the Messrs. Hawkins, chemists, of the Globe Smelting Company of Denver, we are enabled to give analyses of bulk shipments of coal from a number of mines in this state which will give a very fair idea of the average grade coal on the market. They were received too late for publication under their appropriate heads in the earlier pages of this report. They represent averages of from one to five lots.



	Water.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur
Cannon Coal Co. (lump).....	17.84	47.50	29.84	4.82	0.68
" " (slack).....	11.72	42.68	39.57	6.02	
Louisville (slack).....	12.70	43.54	36.30	7.44	
Simpson (lump).....	11.53	43.19	41.53	3.74	
" (slack).....	7.88	45.33	40.81	5.98	
Marshall (lump).....	10.73	44.11	38.38	6.77	
" (slack).....	8.51	45.41	38.26	5.32	1.27
Fort Worth (slack).....	9.50	50.22	34.01	6.27	
Colorado Springs (lump).....	18.04	46.73	30.79	4.42	
C. B. & Q. Coal (lump)....	9.10	45.99	40.19	4.69	
Rock Springs (lump).....	4.42	41.01	49.97	4.54	
Near Rock Springs (lump).....	5.82	27.50	63.60	3.07	
Como (slack).....	2.65	29.84	41.79	25.72	
C. C. & I., Trinidad (lump).....	2.94	34.41	46.01	17.13	
Colorado Fuel Co. (lump).....	2.05	32.51	52.90	12.51	
El Moro (lump).....	0.54	30.29	54.43	14.74	
Baldwin Coal (lump).....	4.57	44.15	43.89	7.39	
Cardiff Coal (lump).....	1.85	37.79	53.82	6.54	
New Castle Coal (lump).....	2.21	36.18	49.71	11.14	

## COKE MANUFACTURED DURING 1889.

<i>Counties.</i>	<i>Tons</i> (2,000 lbs)	<i>Incr'se.</i>	<i>Decr'se.</i>
Gunnison.....	42,858	2,158	
Las Animas.....	119,436		1,298
Pitkin .....	22,125	6,125	
Garfield.....	500	500	
	184,918		

\*The increase and decrease of the coke production is in comparing 1888 with 1889.

\*The above statistics do not include the coke produced in the Durango district (County of La Plata). The Porter and San Juan mines in this district produce coke enough to supply the Durango and Rico smelters, in all three stacks. These, at a moderate estimate, would consume 480 tons of coke per month, when running regularly. We may safely estimate nine months yearly work on their part, which would make a consumption of 4,320 tons of coke yearly, which we would be justified in adding to the above report.







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# ERRATA.

P'GE	LINE	FOR	READ
3	1 from bottom	{ Laboratory Instructor	{ Prof. of Analyt- ical Chemistry
19	5	Laminoes	Laminæ.
26	5 from bottom	Insert quotation marks after "phosphorus."	
37	Plate II	Willow	Arapahoe.
58	Plate III	Willow	Arapahoe.
59	1	Omit "and."	
67	3 from bottom	Geoligists	Geologists.
89	3 from bottom	Indulations	Undulations.
93	3	Mimes	Mines.
104	16	Outline	Outlier.
104	Plate V	Dyke Mountain	Silver Mountain.
112	Last line	"we have "	Prof.Sadtler has,etc
116	22	Boundry	Boundary.
116	29	Stata	Strata.
117	7 from bottom	Tilled	Tilted.
122	9	Later	Latter.
130	23	Granite	Gravity.
140	1	Stream	Steam.
147	3	Continued	Comminuted.
167	3	One	Our.
168	4 from bottom	Verticle	Vertical.
177	9	Prophyry	Porphyry.
183	6	Loose	Lose.
189	7	Hear	Here.
213	11	Blue	Hue.
223	5	Promintory	Promontory.
223	13	Dydes	Dykes.
223	31	Inoceram	Inocerami.



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