COAL OF THE DENVER BASIN, COLORADO.

By George C. Martin.

During the summer of 1908 the writer made a hasty reconnaissance examination of the coal field lying just east of the Front Range of the Rocky Mountains and extending from a point somewhat south of the city of Denver to the north line of the State. As the primary object of the work was the classification of the land, only sufficient time was devoted to the stratigraphy and structure of the rocks to enable the writer to compare his conclusions with those of the previous report[a] by the Geological Survey on this field. No important difference was found, and since the stratigraphic conditions to the north as far as the Wyoming state line are essentially the same as in the Denver region the statements of that report may be considered as applying to the whole field covered by the present paper.

In general the sedimentary formations are steeply upturned against the mountains, but a few miles away the effect of the uplift disappears and the strata are either horizontal or dip slightly toward the east at about the same rate as the slope of the plain. The structure is somewhat complicated near the mountain front by the sharp upturning of the rocks and by minor folds and small faults, which have caused considerable trouble in the mining of coal in this district. This condition, however, is local, and as the throw of the faults is small it has not proved to be a great detriment to the field.

The principal coal beds occur in the lower part of the Laramie formation, which outcrops in a narrow band from a point west of Sedalia nearly to Marshall and there on account of faults and flatter dips expands into a wide belt of outcrop which extends northeastward from Marshall to Louisville and Erie, thence northward almost to the Wyoming state line, where it is covered and concealed by a wide overlap of Tertiary rocks.

Active mining on these coal beds has been carried on for a long time, and in 1908 the combined coal production of Weld, Larimer, Jefferson, Adams, and Arapahoe counties, in which they are situated,

[a] Emmons, S. F., Cross, Whitman, and Eldridge, G. H., Geology of the Denver Basin in Colorado: Mon. U. S. Geol. Survey, vol. 27, 1896.

was 509,038 short tons. The coal meets with a ready sale, although it is inferior to much of the coal from other fields of Colorado, its nearness to a large city and to a region of intensive farming more than offsetting its poor quality.

The coal generally is shiny and black and is inclined to be massive except as it separates along the planes of bedding. Joints are poorly developed and the coal breaks along irregular lines rather than in prisms like coal of a higher grade. On exposure to the air it rapidly parts with its moisture and in the consequent shrinking it breaks to pieces or air slacks. Its percentage of moisture is large, and consequently shipment is expensive. Generally it is shipped in box cars to prevent the escape of moisture and the breaking down of the lump coal.

During the present work a number of samples were taken from the mines of this basin for chemical analysis, and as the sampling and chemical work were done uniformly the results are particularly valuable in that they may be compared directly without the possibility of doing injustice to the product of any particular mine. The sampling, which is by far the most important part of the analytical work, was done by cutting a channel across the coal bed, including everything except the partings or lenses of foreign material which are present at many places. This cut included the entire bed or such part or parts thereof as are mined at that particular place. After being crushed in the mine to avoid loss of moisture and quartered in the usual way the final sample, weighing about 3 pounds, was sent to the chemical laboratory in sealed galvanized-iron cans. By this method the sample reached the laboratory in practically the same condition as it was in at the mine. As in this condition it may have included considerable moisture that in no way belonged to the coal, the sample was air dried in the laboratory to drive off all excess or easily separated moisture and then analyzed in the regular manner.

Each analysis is given in four forms, so that it may be convenient for a variety of uses. The different forms are as follows:

1. As received: Analysis showing composition of the coal as it comes from the mine.

2. Air dried: Analysis of sample after it has been exposed to a temperature a little above that of the ordinary atmosphere and to a current of air. The sample in this condition probably is nearly the same as commercial coal, especially if the latter is shipped in box cars.

3. Dry coal: Analysis recalculated to represent the coal after all moisture has been removed. This form is valuable for purposes of comparison, but it should be clearly understood that it does not represent the coal as mined or as it reaches the consumer.

4. Pure coal: This heading is not strictly correct, for it implies that no foreign material is present, whereas the sulphur has not been eliminated. It is a convenient term, however, and is used in this report to represent coal in the hypothetical condition of having all its moisture and ash removed. Like form No. 3, this is convenient for certain calculations, but in no way represents the coal actually mined and used.

The chemical analyses of samples collected during the course of this work are as follows:

Analyses of coal samples from the Denver Basin, Colorado.

[A. C. Fieldner, chemist in charge.]

Laboratory No.	Location.			Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Sec.	T.	R. W.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
				Ft. in.	*Ft. in.*													
6371	24	4 N.	65	2 8½	2 8½	21.9	As received	29.1	28.5	36.6	5.82	0.30	6.55	48.95	1.03	37.35	4,667	8,401
							Air dried	9.3	36.5	46.8	7.45	.38	5.27	62.67	1.32	22.91	5,976	10,757
							Dry coal	....	40.2	51.6	8.21	.42	4.67	69.07	1.45	16.18	6,585	11,853
							Pure coal [a]	....	43.8	56.2	....	.46	5.09	75.24	1.58	17.63	7,174	12,913
6372	33	3 S.	70	2	2	9.5	As received	18.5	35.5	40.3	5.67	.57	5.76	53.15	.95	33.90	5,217	9,391
							Air dried	10.0	39.2	44.5	6.26	.63	5.19	58.73	1.05	28.14	5,765	10,377
							Dry coal	....	43.5	49.5	6.96	.70	4.54	65.27	1.17	21.36	6,406	11,531
							Pure coal	....	46.8	53.2	....	.76	4.88	70.15	1.26	22.95	6,885	12,393
6373	24	4 N.	65	2 8	2 8	22.9	As received	29.7	27.7	36.5	6.10	.35	6.47	47.16	1.06	38.86	4,486	8,075
							Air dried	8.8	35.9	47.4	7.91	.45	5.10	61.17	1.37	24.00	5,818	10,472
							Dry coal	....	39.3	52.0	8.68	.50	4.51	67.07	1.51	17.73	6,379	11,482
							Pure coal	....	43.1	56.9	....	.55	4.94	73.45	1.65	19.41	6,986	12,575
6374	33	2 N.	68	8	6 3	12.7	As received	21.0	31.2	44.2	3.61	.38	6.13	56.45	1.13	32.30	5,556	10,001
							Air dried	9.6	35.7	50.6	4.14	.44	5.41	64.65	1.30	24.06	6,364	11,455
							Dry coal	....	39.5	55.9	4.57	.48	4.80	71.50	1.43	17.22	7,037	12,667
							Pure coal	....	41.4	58.6	....	.50	5.03	74.92	1.50	18.05	7,374	13,273
6375	30	2 N.	67	8 4	4 6	20.7	As received	25.6	28.0	41.1	5.34	.36	6.27	51.81	1.11	35.11	5,101	9,182
							Air dried	6.2	35.3	51.8	6.74	.46	5.00	65.33	1.40	21.07	6,432	11,578
							Dry coal	....	37.6	55.2	7.18	.48	4.60	69.65	1.49	16.60	6,857	12,343
							Pure coal	....	40.5	59.5	....	.52	4.96	75.04	1.61	17.87	7,388	13,298
6406	32	7 N.	65	2 10½	2 10½	26.1	As received	31.4	28.1	35.1	5.35	.46	6.68	45.57	.96	40.98	4,418	7,952
							Air dried	7.2	38.1	47.5	7.24	.62	5.12	61.66	1.30	24.06	5,979	10,762
							Dry coal	....	41.0	51.2	7.80	.67	4.65	66.44	1.40	19.04	6,441	11,594
							Pure coal	....	44.5	55.5	....	.73	5.04	72.06	1.52	20.65	6,986	12,575
6407	29	3 N.	66	5	1 1	24.5	As received	28.1	29.8	37.9	4.22	.37	6.65	50.46	1.00	37.30	4,863	8,753
							Air dried	4.8	39.5	50.1	5.59	.49	5.20	66.83	1.32	20.57	6,441	11,594
							Dry coal	....	41.5	52.6	5.87	.51	4.91	70.20	1.39	17.12	6,765	12,177
							Pure coal	....	44.1	55.9	....	.54	5.22	74.58	1.48	18.18	7,187	12,937

6408	29	3 N.	66	5		2	4	24.1	As received	28.9	28.8	37.3	5.02	.46	6.64	48.36	.93	38.59	4,703	8,465
									Air dried	6.3	38.0	49.1	6.62	.61	5.22	63.72	1.22	22.61	6,196	11,153
									Dry coal		40.5	52.4	7.06	.65	4.82	68.02	1.31	18.14	6,615	11,907
									Pure coal		43.6	56.4		.70	5.19	73.19	1.41	19.51	7,118	12,812
6433	24	10 N.	68	5	1	5	1	24.9	As received	29.3	29.0	32.7	9.00	3.43	6.28	42.88	.75	37.66	4,149	7,468
									Air dried	5.9	38.5	43.6	11.99	4.57	4.67	57.10	1.00	20.67	5,525	9,945
									Dry coal		41.0	46.3	12.74	4.85	4.27	60.68	1.06	16.40	5,871	10,568
									Pure coal		46.9	53.1		5.56	4.89	69.54	1.21	18.80	6,728	12,110
6593	23	4 S.	70	15	8	14	8	14.8	As received	23.5	34.1	35.0	7.42	.80	6.02	49.26	.60	35.90	4,681	8,426
									Air dried	10.3	40.0	41.0	8.71	.94	5.14	57.82	.70	26.69	5,494	9,889
									Dry coal		44.6	45.7	9.70	1.05	4.46	64.41	.78	19.60	6,120	11,016
									Pure coal		49.4	50.6		1.16	4.94	71.33	.86	21.71	6,778	12,200
6594	23	4 S.	70	15	8	3	8	15.4	As received	23.2	34.1	36.9	5.8	.64						
									Air dried	9.2	40.3	43.7	6.8	.76						
									Dry coal		44.4	48.1	7.5	.83						
									Pure coal		48.0	52.0		.90						
6832	6	1 S.	68	13	2	4		11.4	As received	18.8	31.1	46.2	3.86	.27	6.18	57.47	.99	31.23	5,506	9,911
									Air dried	8.4	35.1	52.1	4.36	.31	5.54	64.87	1.12	23.80	6,215	11,187
									Dry coal		38.3	56.9	4.76	.33	5.04	70.82	1.22	17.83	6,785	12,213
									Pure coal		40.3	59.7		.35	5.29	74.36	1.28	18.72	7,124	12,823
6833	6	1 S.	68	13	2	5	4	13.0	As received	19.7	30.7	43.6	6.00	.33	6.02	56.54	1.02	30.09	4,799	8,638
									Air dried	7.6	35.4	50.1	6.90	.38	5.27	64.99	1.17	21.29	5,516	9,929
									Dry coal		38.3	54.2	7.47	.41	4.78	70.37	1.27	15.70	5,973	10,751
									Pure coal		41.4	58.6		.44	5.17	76.05	1.37	16.97	6,455	11,619
6834	6	1 S.	68	13	2	3	8	16.5	As received	21.2	28.1	44.2	6.53	.46	5.93	55.37	.99	30.72	5,145	9,262
									Air dried	5.6	33.7	52.9	7.82	.55	4.91	66.31	1.18	19.23	6,162	11,092
									Dry coal		35.6	56.1	8.28	.58	4.54	70.21	1.26	15.13	6,525	11,745
									Pure coal		38.9	61.1		.63	4.95	76.54	1.38	16.50	7,114	12,805
6835	14	1 S.	70	6	3	6		12.6	As received	18.9	30.8	47.0	3.29	.26	5.90	58.59	1.09	30.87	5,407	9.733
									Air dried	7.1	35.3	53.8	3.77	.30	5.15	67.03	1.25	22.50	6,187	11,137
									Dry coal		38.0	58.0	4.05	.32	4.68	72.21	1.34	17.40	6,664	11,955
									Pure coal		39.6	60.4		.33	4.88	75.26	1.40	18.13	6,945	12,501
6836	24	1 S.	70	7		7		9.9	As received	17.3	32.1	46.0	4.64	.31	5.96	58.51	1.14	29.44	5,526	9,947
									Air dried	8.2	35.6	51.1	5.15	.34	5.39	64.94	1.27	22.91	6,133	11,039
									Dry coal		38.8	55.6	5.61	.37	4.89	70.77	1.38	16.98	6,684	12,031
									Pure coal		41.1	58.9		.39	5.18	74.97	1.46	18.00	7,081	12,746
6837	8	1 S.	69	10	1	4	7	14.1	As received	20.5	30.5	44.0	5.03	.34	6.10	56.17	1.12	31.24	5,291	9,524
									Air dried	7.4	35.5	51.2	5.85	.40	5.27	65.39	1.30	21.79	6,159	11,086
									Dry coal		38.4	55.3	6.32	.43	4.81	70.61	1.41	16.42	6,651	11,972
									Pure coal		41.0	59.0		.46	5.13	75.38	1.51	17.52	7,100	12,780

[a] "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated, but owing to the briefness and convenience of the term it is used in this report as noted above.

Analyses of coal samples from the Denver Basin, Colorado—Continued.

Laboratory No.	Location.			Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Sec.	T.	R. W.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
				Ft. in.	*Ft. in.*													
6838	8	1 S.	69	6 8¼	6 8	15.1	As received	21.6	27.8	47.0	3.55	.37	5.93	56.06	1.09	33.00	5,282	9,508
							Air dried	7.7	32.8	55.3	4.18	.43	5.00	66.03	1.28	23.08	6,222	11,200
							Dry coal	....	35.5	60.0	4.53	.47	4.51	71.53	1.39	17.57	6,740	12,132
							Pure coal	....	37.2	62.8	....	.49	4.72	74.93	1.46	18.40	7,060	12,708
6839	8	1 S.	69	10 1	3 4	9.8	As received	18.8	30.5	44.5	6.25	.34	6.00	56.35	1.08	29.98	5,360	9,648
							Air dried	10.0	33.8	49.3	6.93	.38	5.44	62.47	1.20	23.58	5,942	10,696
							Dry coal	....	37.6	54.7	7.70	.42	4.81	69.39	1.33	16.35	6,600	11,880
							Pure coal	....	40.7	59.3	....	.46	5.21	75.18	1.44	17.71	7,150	12,870
6840	1	1 S.	69	14 4	6 1	13.4	As received	19.1	30.8	44.3	5.76	.25	5.93	56.38	1.08	30.60	5,342	9,616
							Air dried	6.6	35.6	51.1	6.65	.29	5.13	65.10	1.25	21.58	6,169	11,104
							Dry coal	....	38.1	54.8	7.12	.31	4.70	69.74	1.34	16.79	6,608	11,894
							Pure coal	....	41.0	59.0	....	.33	5.06	75.09	1.44	18.08	7,115	12,807
6841	19	1 N.	68	5 7	5 7	16.7	As received	22.9	29.2	44.4	3.46	.36	6.22	54.94	1.17	33.85	5,305	9,549
							Air dried	7.5	35.0	53.3	4.16	.43	5.23	65.95	1.40	22.83	6,368	11,462
							Dry coal	....	37.9	57.6	4.49	.47	4.76	71.30	1.52	17.46	6,884	12,391
							Pure coal	....	39.7	60.3	....	.49	4.98	74.65	1.59	18.29	7,208	12,974
6842	34	2 N.	68	10 5	8 1	16.2	As received	24.3	27.6	44.8	3.25	.36	6.14	55.28	1.07	33.90	5,209	9,376
							Air dried	9.6	33.0	53.5	3.88	.43	5.18	65.97	1.28	23.26	6,216	11,189
							Dry coal	....	36.5	59.2	4.29	.48	4.54	73.01	1.41	16.27	6,880	12,384
							Pure coal	....	38.1	61.9	....	.50	4.74	76.28	1.47	17.01	7,188	12,938

Location and description of coal samples.

No.	Town.	County.	Name of mine.	Section of coal bed.	Location in mine.	Depth below surface.	Condition of sample.
				Ft. in.		*Feet.*	
6371		Weld.	White Ash.	*Coal, bony..... 2 *Coal............ 2 6½ 2 8½	700 feet northwest of foot of shaft.	85	Dry, fresh.
6372		Jefferson.	Ralston Creek.	*Coal........... 2	500 feet north of opening.	75	Dry, fresh.
6373		Weld.	Farmers.	*Coal........... 2 8	500 feet south of foot of shaft.	70	Dry, fresh.
6374		Weld.	Ideal.	Coal............. 1 9 *Coal........... 6 3 8	300 feet west of foot of slope.	100	Dry, fresh.
6375		Weld.	Warwick.	Coal............. 2 8 Shale............ 4 Coal, bony....... 10 Parting. *Coal........... 4 6 8 4	165 feet south of foot of shaft.	115	Dry, fresh.
6406	Eaton.	Weld.	Star.	*Coal........... 2 10½	325 feet southeast of foot of shaft.	50	Dry, fresh.
6407	Platteville.	Weld.	Platteville.	Coal............. 2 4 Bone and coal.... 1 7 *Coal........... 1 1 5	200 feet west of foot of shaft.	56	Dry, fresh.

* Part sampled.

Location and description of coal samples—Continued.

No.	Town.	County.	Name of mine.	Section of coal bed.	Location in mine.	Depth below surface.	Condition of sample.
				Ft. in.		*Feet.*	
6408	Platteville.	Weld.	Platteville.	* Coal............ 2 4 Bone and coal.... 1 7 Coal............ 1 1 5	200 feet west of foot of shaft.	56	Dry, fresh.
6433		Larimer.	Indian Springs.	*Coal............ 5 1 Bone............ 1 1 6 2	In main entry 700 feet N. 70° E. (magnetic) of mouth of slope.	50	Dry, probably weathered.
6593	Morrison.	Jefferson.	Morrison.	Coal............ 7 Coal, bony....... 5 *Coal............ 14 8 15 8	50 feet north of shaft on the 73-foot level.	73	Dry, fresh.
6594	Morrison.	Jefferson.	Morrison.	Coal............ 7 Coal, bony....... 5 Coal............ 10 11 *Coal............ 3 9 15 8	Bottom of shaft on 120-foot level.	120	Wet, fresh.
6832	Lafayette.	Adams.	Parkdale.	Coal............ 4 10 *Coal............ 4 Bone and shale... 8 Coal............ 3 8 13 2	200 feet east of foot of slope, close to fault.	200	Dry, fresh.
6833	Lafayette.	Adams.	Parkdale.	Coal............ 3 6 *Coal............ 5 4 Bone and shale... 8 Coal............ 3 8 13 2	150 feet west of foot of slope.	260	Dry, fresh.

6834	Lafayette.	Adams.	Parkdale.	Coal.............. Bone and shale... *Coal............ 	8 3 13	10 8 8 2	150 feet west of foot of slope.	260	Dry, fresh.
6835	Marshall.	Boulder.	Mitchell-Monarch.	*Coal............ Coal.............. 	6 6	 3 3	75 feet north and 350 feet east of foot of shaft.	235	Dry, fresh.
6836	Superior.	Boulder.	Industrial.	*Coal............	7		1,200 feet east and 450 feet south of foot of shaft.	250	Dry, fresh.
6837	Louisville.	Boulder.	Acme.	Coal.............. Shale............. *Coal............ *Parting. *Coal............ 	5 1 2 10	2 4 8 11 1	800 feet south and 950 feet east of foot of shaft.	185	Dry, fresh.
6838	Louisville.	Boulder.	Acme.	*Coal............ *Parting......... *Coal............ 	3 3 6	8 ¼ 8¼	950 feet north and 400 feet east of foot of shaft (north of fault).	200	Dry, fresh.
6839	Louisville.	Boulder.	Acme.	Coal.............. *Coal............ Shale............. Coal.............. Parting. Coal.............. 	1 3 1 2 10	10 4 4 8 11 1	800 feet south and 950 feet east of foot of shaft.	180	Dry, fresh.
6840	Lafayette.	Boulder.	Rankin.	*Coal............ Bone and shale... Coal.............. Shale............. Coal.............. 	6 4 2 1 14	1 11 4 4	200 feet north and 200 feet east of foot of shaft.	210	Dry, fresh.

*Part sampled.

Location and description of coal samples—Continued.

No.	Town.	County.	Name of mine.	Section of coal bed.	Location in mine.	Depth below surface.	Condition of sample.
				Ft. in.		*Feet.*	
6841	Erie.	Weld.	Lehigh.	*Coal............ 5 7	750 feet north of foot of shaft.	100+	Dry, fresh.
6842		Weld.	Puritan.	Coal.............. 2 4 *Coal............ 8 1 10 5	175 feet west of foot of shaft.	110	Dry, fresh.

*Part sampled.

THE SOUTH PARK COAL FIELD, COLORADO.

By Chester W. Washburne.

INTRODUCTION.

The coal field described in this paper is located in the eastern part of South Park, an intermontane depression in central Colorado. The Kenosha Range on the northeast and the Puma Hills on the east of the park are western spurs of the Front Range of the Rocky Mountains. West of the park lies an irregular group of mountains called the Mosquito Range, beyond which is the Leadville mining district.

The following pages contain a brief summary of the results of a reconnaissance made in September, 1908. The topography and geology in the vicinity of the coal outcrops were sketched from traverses carefully tied to land corners, but elsewhere no attempt was made to do detailed work.

No coal is now produced in South Park. Between 1875 and 1893 the King mines, near Como, were worked on a large scale by the Union Pacific Coal Company, but they were abandoned after the best and most easily available coal had been mined. It is probable that extensive operations will not be resumed for many years, because of the difficulty in finding coal beneath the cover of gravel and weathered rock and of the apparent absence of thick coal beds.

GENERAL GEOLOGY.

The general geology of South Park may be briefly summed up in the statement that the park consists of two downthrown fault blocks between the Mosquito Range on the west and the spurs of the Front Range on the east. The eastern fault block, which includes the greater part of the area that is possibly underlain by coal, is a syncline, the eastern limb of which is cut off by the fault throughout the central part of the field. The western fault block, in which the coal formation remains only as a small remnant west of Como, has a monoclinal structure, its beds rising gradually westward to the summit of the Mosquito Range, where they are terminated by the great London and Mosquito faults.[a]

[a] Geology and mining industry of Leadville, Colo.; Mon. U. S. Geol. Survey, vol. 12, 1886.

The coal beds are involved in both folds and faults. In the western block they dip 45° E. until cut off by the South Park fault underneath Como. In the eastern fault block the coal is folded in a syncline, the eastern part of which has been removed by faulting, as shown on the map (Pl. XVI). A remnant of the east limb of the syncline is preserved at Jefferson Hill, 1 mile north of Jefferson, where the coal bed dips about 50° W. North of this locality the outcrop of the coal bed probably swings around the end of the syncline and runs southward to the prospects in sec. 23, T. 8 S., R. 76 W., where the bed stands nearly vertical. South of these prospects the dips become gradually lower, being about 45° E. at the King mines and 20° E. near the south end of the syncline. On following the coal horizon northward from the south end the dips of the east limb of the syncline are found to vary from 30° to 50° W. until the coal bed again disappears against granite at the Elkhorn fault.

As coal occurs only in the "Laramie" formation, a description of the other formations is not necessary in this paper.

THE COAL.

STRATIGRAPHIC POSITION.

The coal beds of South Park occur in what is presumably the "Laramie" formation, consisting of sandstone with subordinate beds of carbonaceous shale and ranging in thickness from 375 feet down to the vanishing point. No fossils have been found in the formation, but as it rests on a yellow sandstone containing upper Montana marine fossils and is unconformably overlain by conglomerate beds that are undoubtedly equivalent to part, at least, of the Shoshone group, as typically developed in the Denver Basin, it seems to correspond to the Laramie according to King's definition.

Three coal beds are present in the "Laramie" where the entire formation is present. The lowest coal bed, which is usually the best, is regarded as the base of the formation and rests directly and conformably on the upper Montana sandstone. The second coal bed occurs about 187 feet above the lower coal in sec. 23, T. 8 S., R. 76 W., and about 175 feet above it in sec. 2, T. 9 S., R. 76 W. The upper coal bed lies about 221 feet above the middle coal in sec. 23, T. 8 S., R. 76 W., and 175 feet above it in sec. 2, T. 9 S., R. 76 W.

The formation attains its maximum thickness between secs. 23 and 2, mentioned above, where all three coal beds are present. About a mile south of sec. 2 the unconformity at the top of the "Laramie" cuts down into that formation, which within a few miles completely dies out, allowing the conglomerate to rest directly on the marine upper Montana sandstone. This condition prevails over the greater part of the coal field, and the "Laramie" is therefore absent in most places where it should normally occur. The details of its distribution are given in the following pages.

DISTRIBUTION.

The most northern exposure of coal in South Park is on Jefferson Hill, on the southern margin of T. 7 S., R. 75 W., about a mile north of the town of Jefferson. Here thin beds of coal were discovered in a well dug at Mr. Lilley's house, near the southeast corner of sec. 32. About 12 or 14 inches of coal is reported from a small abandoned prospect 300 feet west of this well. Samples of this coal, which had been dug about ten years, were shown to the writer by Mr. Lilley. The coal appeared to be of good quality, very hard and brilliant, and to show well-developed cubical cleavage. Coal smut was brought up by the drill from a horizon about 20 feet above the coal bed on which the prospect was driven. On Jefferson Hill the coal-bearing formation has a possible thickness of 250 feet.

In this township the position of the coal bed is entirely unknown except on Jefferson Hill. The location of the dotted line on the map that marks the hypothetical position of the coal bed is based largely on the supposition that the sill of porphyry which outcrops at Sheep Rock lies parallel to the sedimentary strata. It is possible, however, that this porphyry is intruded along a fault and that the coal bed is cut off by the porphyry and does not bend around toward the west in the manner indicated on the map. There appears to be no way of determining the position of the coal bed. Deep drilling would not be likely to strike it on account of the high dip of the rocks. South of the Jefferson Hill locality there is no exposure on the east limb of the syncline. The coal bed probably runs into the granite at some place in the southern part of T. 8 S., R. 75 E.

West of Jefferson Hill the north end of the syncline is not exposed. The coal bed may possibly encounter intrusive igneous rocks, as mentioned above, but more probably it lies concealed beneath the alluvium. The southeast corner of T. 7 S., R. 76 W., within which the coal must outcrop if present, is entirely covered by alluvium. The position of the bed indicated by the dotted line on the map is only a rough guess at the place where the coal may outcrop if present. This line may be as much as a mile too far northwest or half a mile too far southeast. It is given a curved form in order to make it more or less parallel with the outcrop of a deformed sill of igneous rock that is exposed conspicuously at Sheep Rock and other places. It is not likely that the coal bed remains beneath the conglomerate in this locality, because elsewhere in the park it has generally been removed by pre-Shoshone erosion, indicated by the unconformity mentioned above. Wherever measured in South Park the coal bed is not workable except near Como, in the southern part of T. 8 S., R. 76 W., and the northern part of T. 9 S., R. 76 W. As the rocks of the South

Park region are so deeply weathered that it is necessary to penetrate about 50 feet below the surface before reaching fresh coal, as the coal-bearing rocks in T. 7 S., R. 76 W., probably lie at angles of 45° to 90°, and as they are covered by an unknown amount of alluvium, possibly more than 100 feet thick, it seems improbable that coal will be found in this township, even if it is present.

In T. 8 S., R. 76 W., the "Laramie" formation is exposed in the old Como mine, about half a mile northwest of Como, and in several prospects in secs. 23, 26, and 35. It is also reported in a prospect in the NW. ¼ NE. ¼ sec. 19. The formation is absent in places, but where present ranges in thickness up to 425 feet, the variation being due to erosion which took place before the deposition of the overlying conglomerate of Shoshone age. The formation consists principally of sandstone and contains from one to three beds of coal.

It is said that at the old Como mine, in the NE. ¼ SE. ¼ sec. 29, T. 8 S., R. 76 W., which was abandoned in 1883, there was a pocket of coal 5 to 6 feet thick extending along the strike for about half a mile. At a distance of 300 feet down the slope a fault was encountered which brought sandstone against the coal. Operations were stopped at this fault. The writer believes that the downthrow is westward and that the fault is not large enough to repeat the outcrop of the coal bed. If this conclusion is correct, there must be a good bed of coal underlying the western margin of the SW. ¼ sec. 28. The conglomerate of the Shoshone group is exposed in a large well sunk by the Colorado and Southern Railway in the NE. ¼ SW. ¼ sec. 28. This occurrence substantiates the idea that coal could be found by drilling through the alluvium in the western part of sec. 28. The Como mine was inaccessible in 1908, being entirely caved in and filled with water. Many people in Como substantiated the report that the coal bed was 5 to 6 feet thick. Only one coal bed was reported, but it is believed from the distribution of the prospects that two beds may be present.

The following reference to the mine made by A. C. Peale [a] in 1873 partly corroborates this opinion:

> Near Lechner's ranch a shaft has been sunk about 30 feet deep, cutting a coal bed about 12 feet in thickness, with a dip of 45° NE. and a strike S. 45° E. The clay above the coal is about 6 inches and below the coal 10 inches thick. Below the lower clay is a sandstone, at the bottom of the shaft, and above the upper clay a bed of yellow soft sandstone. About 200 yards to the west another shaft has been sunk, exposing a bed of coal 6 feet thick. I am inclined to think there are two different coal beds here, though there may be but one. The slope underlaid by the coal strata extends up close to the sides of the mountain, and the surface is so covered with drift that it is only by means of these shafts that the Lignitic beds can be seen at all. A few fragments of deciduous leaves have been collected here, showing clearly that a portion of the Lignitic group, as seen on the east side of the mountain range, occurs here.

[a] Seventh Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1873, p. 38.

In 1876 W. B. Potter[a] describes this mine as follows:

The Lechner coal [is] worked by Mr. George W. Lechner, 1½ miles from Hamilton and 8 miles northeast of Fairplay, in the South Park. The seam is about 12 feet thick and the coal is of rather dull luster, uneven fracture, and exhibits a tendency to slack when exposed to the air and when heated. It burns freely without changing form and yields no coke.

On the north side of Tarryall Creek, in the NW. ¼ NE. ¼ sec. 19, T. 8 S., R. 76 W., Mr. Rogers showed the writer a prospect where a few inches (6 to 10?) of coal was found several years ago. This prospect had caved in and was filled with gravel from the wash of Tarryall Creek.

In the belt of coal extending through secs. 23, 26, and 35, T. 8 S., R. 76 W., three coal beds are present. Of these beds the lower one appears to be the best, but it is not workable at Mr. Arthur's prospect, in the NW. ¼ SE. ¼ sec. 23. At this place there is about 12 inches of bony coal at the horizon of the lower coal bed. In Mr. Dunbar's prospect, near the north quarter corner of sec. 26, about 2 feet of dirty coal and bone are exposed, according to the reports of people in Como. The coal contains many partings of carbonaceous shale, and is not workable. In a prospect in the SE. ¼ SW. ¼ sec. 26, sunk by Judge Foote, about a foot of clean coal and 3 to 4 inches of coal smut are reported at a depth of 45 feet. It is probable that this prospect was not deep enough to get through the zone of surface weathering, which is unusually deep in this region and has a marked influence in reducing the apparent thickness of the coal bed. At Mr. Arthur's second prospect, on the middle (?) bed, in the SE. ¼ SW. ¼ sec. 26, about 300 feet east of Judge Foote's prospect, 18 inches of clean coal was found at a depth of about 20 feet. The thickness increased to 22 inches at a depth of about 45 feet, remaining constant at this figure to the bottom of the prospect, which was about 60 feet deep at the time of the writer's visit. The coal, however, was not fresh even at that depth, although probably the bed had reached its full thickness. In spite of the high dip of the rocks, 45°, it is thought possible to work the coal bed for local use. A company known as the South Park Coal Company has been organized for this purpose by John Arthur, of Canon City, M. B. Burke, of Cripple Creek, and others.

The third or highest coal bed is very poorly developed, according to all reports, and is doubtless of no value in this township. It is said that at a prospect on this coal bed sunk about twenty years ago in the SW. ¼ SE. ¼ sec. 23, there was about 18 inches of dirty coal.

The rocks between the coal beds are not visible except at a few small exposures. In sec. 23 the stratigraphic interval between the lower and middle coal beds is 187 feet and that between the middle and upper coal beds is 221 feet.

[a] The lignite coals of Colorado: Trans. Am. Inst. Min. Eng., vol. 5, 1877, pp. 365, 375.

In secs. 2 and 11, T. 9 S., R. 76 W., are located the old King mines of the Union Pacific Coal Company. At this place is the best development of coal known in the South Park region. In these mines, which were abandoned in 1893, three coal beds were worked, of which the upper two are said to have varied in thickness from 4 to 6 feet and the lower one from 7 to 40 feet. This lower bed had an average thickness of 7½ feet in the upper part of the mine and of 8 feet in the lower part. It was 8 feet thick at a depth of 2,000 feet, the maximum depth reached in mining. The thickness of 40 feet was apparently due to a large pocket about 500 feet in depth and 1,000 feet in length. It is thought to be the result of shearing and crumpling. Several pockets from 15 to 20 feet thick are reported as occurring in other parts of the mine. A section of the bed measured in 1908 is as follows:

Section of coal strata in S. ½ sec. 2, T. 9 S., R. 76 W.

	Ft.	in.
Upper coal not exposed.		
Rock, principally sandstone, not exposed	150	
Sandstone, massive	25	
Coal, middle	2	9
Sandstone, thin bedded	8	
Rock, principally sandstone, not exposed	167	
Coal, lower	7	
	359	9

The upper coal bed is said to be 4 feet thick, but this statement can not be verified. The lower coal bed rests on sandstone which contains upper Montana fossils. The intervals between the coal beds are variant, owing to changes in thickness of the beds due to differences in original deposition or to subsequent deformation and to the injection of small masses of igneous rock.

The condition of the King mines in 1902 has been described by R. C. Hills[a] as follows:

Slopes No. 5 and No. 6 * * * turn out about 150 tons per day. * * * The inclination of the western outcrop ranges from 30° to 50°, being about 45° at No. 5 and 33° at No. 6, but less than this to the southward. Along the eastern border the Laramie outcrop is overlapped by what is probably the post-Laramie formation, which is found resting on the border of the granite hills bounding the district to the eastward,.

The seam worked at No. 5 contains from 5 to 7 feet of coal in the lower bench and 2 feet in the upper bench, which is separated from the lower by from 8 inches to 3 feet of shale. At No. 6, which is about a mile south of No. 5, the seam worked is only 4½ feet thick. It is not certain that these openings are on the same seam, though this appears most probable. But the intrusion, both above and below the coal, of sheets of eruptive conglomerate which, a short distance south of No. 6, consolidate into one large body and thus determine the southern limit of the productive outcrop, throws some doubt on the identity of these seams until further extension of the respective workings shall have settled the question. Workable coal has been opened up some distance north of No. 5, but the locality is badly faulted. There is also another opening near the railway track

[a] The coal fields of Colorado: Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, p. 338.

[Como mine], on the opposite side of the Laramie area. The South Park coal cakes strongly, * * * but, all things considered, the district has less prospective value than any other independent area in the State.

Arthur Lakes[a] reports that the principal coal at the King mines is 7 feet thick, but that many faults hinder development. He states that in 1885 the production of No. 1 mine was 58,997 tons.

In the N. ½ sec. 2 the horizontal distance between the upper and lower coal beds is 600 feet. The dip is variant, ranging from 40° E. to 90°, and averaging probably about 45° E. The thickness of the rocks between the upper and lower coal beds is therefore about 425 feet, including a 50-foot intrusive sill of hornblende andesite and about 375 feet of sedimentary strata.

In the SW. ¼ NE. ¼ sec. 14, T. 9 S., R. 76 W., 4½ feet of clean coal is exposed in a coal prospect. This is thought to be the lower coal bed, but it may be the middle bed. In a prospect in the NW. ¼ SE. ¼ sec. 14 about 2 feet of coal was seen, but the bottom of the bed was concealed and could not be reached by the means at hand. At this place the coal bed is overlain by 8 feet of thin-bedded soft yellow sandstone, at the top of which is an erosional unconformity followed by conglomerate of the Shoshone group. As this is doubtless the lowest coal bed, it is evident that the upper beds and the rest of the "Laramie" formation had been removed by erosion before the deposition of the conglomerate. It is thought that south of this point the "Laramie" is entirely removed for several miles. In the SW. ¼ SE. ¼ sec. 14, three-eighths of a mile south of the last-mentioned locality, the conglomerate was found resting directly on the marine upper Montana sandstone (Fox Hills?). A similar observation was made in the NW. ¼ NW. ¼ sec. 35. No trace of coal could be found along the outcrop south of this point, although the débris ejected from prairie-dog holes was thoroughly examined and a prospecting drill was used about every half mile along the line where the "Laramie" should outcrop if present. There are no good exposures of the formation, owing to the covering of talus from the more resistant overlying conglomerate.

A few thin beds of coal were found in a prospect in the NE. ¼ NW. ¼ sec. 21. At this locality the rocks strike east and west and dip about 15° S. The "Laramie" formation is entirely covered by alluvium. It is probably cut off on the west by an intrusive mass of andesite porphyry. In secs. 29 and 32 the coal bed may possibly be present along the western margin of the andesite, as sandstone that resembles that at the top of the Montana group (Fox Hills? sandstone) is exposed near this margin. However, no trace of coal, carbonaceous shale, or sandstone of the "Laramie" formation could be found in these sections.

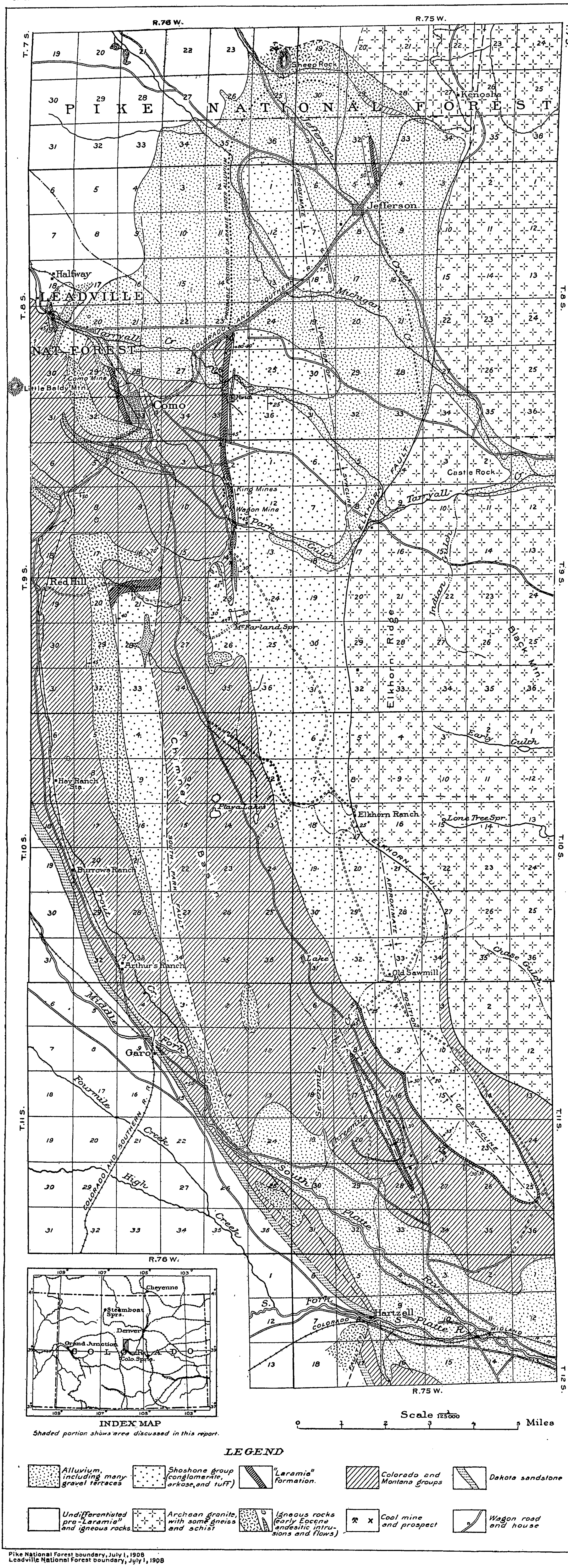
[a] The South Park coal field [Colorado]: Min. Rep., vol. 51, 1905, pp. 428-429.

No sign of coal was found in following the formation through T. 10 S., R. 76 W., although careful search was made for it by using a prospecting drill with which a depth of about 15 feet could be reached. In going southward the first sign of coal was obtained in the NW. ¼ SE. ¼ sec. 5, T. 11 S., R. 75 W., where the drill brought up some coal smut. Coal is exposed a short distance southwest of this point, in prospects in the southern part of the small syncline that runs through secs. 8, 17, 16, 21, and 28. The coal bed could not be accurately measured, but probably is less than a foot thick. The only place where the "Laramie" rocks are well exposed in this township is on a bluff in sec. 25, at the south end of the outcrop of rocks of the Shoshone group. Here there is about 50 feet of sandstone, barren of coal but containing layers of carbonaceous shale which may possibly belong to the "Laramie" formation. It rests conformably on marine upper Montana sandstone (Fox Hills?) and is unconformably overlain by conglomerate.

In a prospect near Myner's old house, in the NW. ¼ NE., ¼ sec. 28, 12 inches of coal is exposed. The coal is overlain and underlain by yellow sandstone. Fragments of coal were found on the dumps of old prospects in the NW. ¼ SE. ¼ and the SE. ¼ SW. ¼ sec. 21.

The coal zone is not exposed on the east limb of the syncline in T. 11 S., R. 75 W. The "Laramie" outcrop, if present, is concealed in places by débris from the ridge of conglomerate on the west and in places by débris from the granite hills on the east. On account of the apparent great quantity of débris it was thought useless to attempt to reach the coal with the short prospecting drill that was used in the field. The exact location of the coal horizon on the eastern limb of the syncline in this neighborhood is not known, but it must be very close to the position of the Montana-Shoshone boundary shown on the map and probably runs into the granite along the Elkhorn fault near the northern edge of T. 11 S.

The coal-bearing rocks may possibly be present on Reichenecker Ridge, but no evidence of them could be found, although the underlying marine upper Montana sandstones are exposed on the west side of the hill, and the overlying conglomerate of the Shoshone group is exposed on the east side of the hill. Between these two, on the summit and west slope, is a large mass of igneous rock consisting of andesite breccia and biotite porphyrite, the débris of which probably conceals any "Laramie" rocks that may be present. It is possible that the "Laramie" may be found on one side or the other of this igneous mass, either along the western foot of the ridge or east of the summit. Careful search during the reconnaissance of 1908 failed to reveal any trace of the formation on this ridge, except at the old prospect in the NE. ¼ NW. ¼ sec. 21, T. 9 S., R. 76 W., where a few thin beds of coal were found in yellow sandstone, probably of "Laramie" age. The



MAP OF SOUTH PARK COAL FIELD, COLORADO.

By C. W. Washburne.

sandstone strikes nearly east and west and dips about 15° S. It is entirely concealed by alluvium except in the prospect. On the east it must terminate at the South Park fault, and on the west it is probably cut off by the intrusive mass of porphyry and andesite breccia mentioned above.

CHARACTER.

No fresh samples of the South Park coal could be obtained and consequently no chemical analyses were made during this examination. The only analyses available are two made a number of years ago when the mines of the field were in active operation. These analyses are as follows:

Analyses of coal samples from the South Park coal field, Colorado

	Proximate.				Ultimate.				
	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.
Lechner mine [a]	6.3	33.8	58.6	1.28	0.47	5.93	71.50	2.35	18.47
Mine No. 5 [b]	7.2	38.7	49.4	4.70	.53	5.03	66.55	1.06	22.37

[a] Potter, W. B., Trans. Am. Inst. Min. Eng., vol. 5, 1877, p. 368.
[b] Hills, R. C., Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, p. 362.

Although the quoted descriptions differ somewhat regarding the character of the coal, there can be little doubt that most of it is bituminous. It has well-developed cubical joints, is hard and lustrous, and gives a black streak. It is said that the coal cakes rather poorly in the beehive oven and that a large plant erected at Como about 1880 for the manufacture of coke did not obtain a good product. The coal stocks remarkably well, as shown by the fact that large lumps 6 inches or more in diameter were dug out of the dumps of the old mines, where they had been partly exposed to the weather for over ten years. These fragments were firm and hard, and although they broke readily along the joint planes when struck by the hammer, they did not crumble as a coal of poor grade certainly would after so long an exposure. When the Pishel test for determining coking coal is applied to these fragments they respond very poorly, the pulverized coal adhering but slightly to the sides of the mortar, but as weathering interferes greatly with the coking quality of coal, this can not be regarded as a fair test. Owing to the fact that all the mines had been abandoned many years before the writer's visit and were full of water or choked with débris, it was impossible to procure a fresh sample of coal for analysis. The outcrops of the coal are badly weathered, in places to depths of 50 feet or more, and they are covered by alluvium and talus to depths ranging from a few feet to several hundred feet. There are no natural exposures in the park.

CONCLUSION.

The coal of South Park is bituminous and of excellent quality for steaming purposes. The quantity available is unknown, and it seems unwise with the scanty evidence obtained during this examination to attempt any estimate of this quantity. In none of the prospects examined was the coal of satisfactory thickness. The future of the field is problematical and depends on the discovery of beds of workable thickness. Probably near the old King mines and possibly near the Como mine there is considerable coal which was not removed by the early operations. This can be mined if sufficient care is taken to avoid dangerous flows of water from the adjacent old mines, all of which are completely flooded at the present time.

THE COLORADO SPRINGS COAL FIELD, COLORADO.

By Marcus I. Goldman.

INTRODUCTION.

LOCATION AND EXTENT.

The part of the Colorado Springs coal field described in this report lies in El Paso County, Colo. Its southern limit is the outcrop of the coal-bearing sandstone and shale which extends from the region just north of Colorado Springs in a direction a little south of east to T. 15 S., R. 62 W. The northern limit is indeterminate, for the coal-bearing rocks pass under cover in that direction and all development and exploration are less than a mile back from the outcrop; hence statements regarding the presence and condition of the coal at a greater distance are only assumptions. The western limit of the field is also indeterminate, but may be taken as the locality in T. 13 S., R. 67 W., at which the coal-bearing beds pass under the cover of gravel adjacent to the mountains. Coal, however, is not exposed west of the Monument Valley mine, in sec. 11, T. 13 S., R. 67 W. In the opposite direction the outcrop of the coal zone can be traced (with interruptions due to a cover of soil) in a direction somewhat south of east for about 40 miles.[a]

The coal outcrop was examined with considerable care, but in the area to the north a much less detailed examination was made.

From its outcrop, as described above, the coal dips gently to the northeast, generally at about 3° to 5° with local increases up to 8° or 10°. From the low dips it is believed that the coal-bearing strata extend under the divide between Platte and Arkansas rivers, coming to the surface again a little south of Denver. On account of this connection the Colorado Springs field is regarded as part of the larger Denver coal region. It also seems probable that the coal-bearing rocks originally continued far to the south, but they have been carried away by erosion, leaving only isolated fields along the base of the Front Range.

[a] Hills, R. C., Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, p. 332. Storrs, L. S., Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1902, p. 432.

The Colorado Springs field lies 18 or 20 miles south of the Platte-Arkansas divide, which runs eastward from Palmer Lake, and its general slope is toward the south. The largest stream in the field and the only one that is permanent is Monument Creek, near the western edge. The valley of this stream forms one of the principal lines of communication between Denver and Colorado Springs, and it is utilized by the Denver and Rio Grande and the Atchison, Topeka and Santa Fe railroads.

For some distance east of Palmer Lake the divide is somewhat rough, so that the Colorado and Southern Railroad, which follows a plains route from Colorado Springs to Denver, is obliged to make a detour of about 15 miles in order to find a satisfactory grade. The only other obstacle to lines of communication across the plains is Corral Bluffs, about 12 miles east of Colorado Springs.

South of Colorado Springs the valley of Fountain Creek forms the most convenient line of communication with Pueblo, though the country is so open that roads and railroads could be built in almost any direction.

Communication with Cripple Creek through the mountains to the west is of course difficult, yet that town is entered by two railroads from Colorado Springs. The Colorado Midland ascends slowly through Ute Pass, and the Colorado Springs and Cripple Creek District (Colorado and Southern) plunges directly into the mountains through North Cheyenne Canyon.

PREVIOUS GEOLOGIC STUDIES.

The two reports that contain the fullest information on this field are those of A. C. Peale[a] and R. C. Hills.[b]

At the time Peale's report was written there were no mines of any commercial importance. One known as the Gehrung mine, believed to have been situated on the east bank of Monument Creek, a little south of the present Carlton mine, had not proved to be very successful and the old Franceville mine was not yet open, though Peale states that he went out with Mr. France to see the coal, then as now exposed in a stream course at the west edge of sec. 19, T. 14 S., R. 64 W. Peale concerned himself mainly with the geology of the foothills and mountains. At the time Hills made his report mining was more extensive, the Franceville and McFerran mines had been well developed, and the extent of the field was understood, though the large mines north of Colorado Springs had not yet been opened.

[a] Ann. Rept. U. S. Geol. and Geog. Survey Terr. for 1873, 1874, pp. 193-270.
[b] Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, pp. 319-365.

GENERAL GEOLOGY.

For a fuller account of the general geology of this region the reader is referred to the forthcoming Colorado Springs folio, which is being prepared by G. I. Finlay. For present purposes it will be sufficient to outline the general geology of the beds associated with coal, which was worked out by Professor Finlay and the writer jointly. The discussion begins with the Pierre shale.

STRATIGRAPHY.

PIERRE SHALE.

The Pierre shale underlies the entire coal field and outcrops in an extensive region to the south and east of Colorado Springs. It is a dark-gray clay shale which in the vicinity of Colorado Springs is approximately 3,000 feet thick. The monotony of this great mass of shale is relieved by the local occurrence of concretions composed of carbonate of lime and carbonate of iron, which weather to small fragments of a rusty brown color. The Pierre shale also contains lenses of gray limestone which because of their relative hardness in places form prominent conical hills known as "tepee buttes." The Pierre shale grades upward by an increasing abundance of sand into the overlying Fox Hills sandstone.

FOX HILLS SANDSTONE.

In places where it has been impregnated with lime the Fox Hills sandstone is of a deep reddish brown color, but the upper portion, near the contact with the Laramie, is generally a light-yellow, nearly pure quartz sandstone. Calcareous sandstone concretions from a few inches up to 3 or 4 feet in diameter, and generally with a fossil imprint of a seaweed at the center, are common in the sandstone.

In most places it is not possible to draw a sharp line between the sandstone at the base of the Laramie and that at the top of the Fox Hills. The latter is typically somewhat micaceous, whereas the former contains minute grains of black chert and no mica. Generally, however, there is no sharp distinction between them. The only exposure in which there seems to be a definite line between the Fox Hills and Laramie is that at Crows Roost, on Black Squirrel Creek. Here the Laramie also is concretionary, but there is a distinct difference in bedding, texture, and character of contained concretions between the two formations.

LARAMIE FORMATION.

Above the Fox Hills sandstone lie the coal-bearing rocks of Laramie age. These may be divided into two members—a lower including several massive sandstone beds and three of the most important coal beds of the field, and an upper composed of clay shale, sandy shale, and some sandstone with poorly developed coal beds.

The best exposure of the sandy, coal-bearing member is in Popes Bluff, where the base of the formation is composed of a massive sandstone from 40 to 100 feet thick, but not sharply defined from the underlying Fox Hills. The upper part of the sandstone member of the Laramie gives way gradually, toward the east, to shale with thin beds of calcareous and ferruginous sandstone about 250 feet thick. In the western part of the field the sandy member is about 200 feet thick.

The shaly member covers more than a square mile west of the Pikeview mine and in section it is well exposed on the slope below Pulpit Rock, where its thickness is about 150 feet.

ROCKS ABOVE THE LARAMIE.

Paleontologic evidence, mainly that of fossil leaves, is at present too incomplete to permit definite correlation of the formations overlying the Laramie. In the following descriptions attention is drawn to the lithologic similarities of these rocks to formations in the Denver region, but the subdivision and naming of the beds is left to the future.

Conglomerate.—In some parts of the field the shaly part of the Laramie is overlain by a conglomerate containing some pebbles of sedimentary rocks but mainly of rusty quartz. The pebbles range from 1 inch to 2 inches in diameter. In places a very pure, hard white quartzose sandstone takes the place of the conglomerate. The maximum known thickness of the bed is about 30 feet, in an exposure on Monument Creek back of the Curtis mine, a few hundred feet west of the Cragmore sanitarium. The lithologic similarity of this bed to some parts of the Arapahoe formation in the Denver Basin is apparent.

Andesitic material.—The conglomerate is overlain by beds of andesitic material, which in lithologic composition is similar to the Denver formation. Where exposed in natural outcrop these rocks are mainly yellow, yellowish green, and cream colored, with a few beds 1 to 2 feet thick of black, leaf-bearing coaly shale and of limonite, generally not more than 1 foot thick and in places full of plant fragments. Most of this rock is very soft, so that material from the upper beds washes down over those below, covering the contacts. In places there is a pebble bed composed of well-rounded fragments, averaging half an inch in diameter, of andesite in a matrix apparently of the same material.

The most complete exposures of the beds containing andesitic material were observed in the bluffs underlying Pulpit Rock on the west bank of Monument Creek, opposite Pikeview (see section 22, p. 328), and along the west fork of Jimmy Camp Creek south of the Richfield

Springs ranch and just north of the county road. The pebble bed is present in the Pulpit Rock section, where it is about 18 feet thick.

The average thickness of the beds of andesitic material is about 125 feet.

Arkose.—Beds of arkose lie unconformably upon the andesitic material and overlap the coal-bearing sandstone in the southeast corner of sec. 6, T. 13 S., R. 67 W. The arkose has two phases—(1) coarse arkose near the mountains, some sandstone, and clay containing coarse quartz grains; (2) fine-grained, very micaceous sandstone. Both phases are very irregularly bedded, and most of the lithologic units are of small horizontal extent. An exception to this discontinuity is a bed of conglomerate within 10 feet of the base. This was not observed near the mountains, but is well exposed on Jimmy Camp Creek and was found also in a stream channel just east of the Franceville schoolhouse. The pebbles range from half an inch to 1 inch in diameter and are siliceous, brightly colored, and rounded, and have glossy surfaces. The surface of the road beyond the first crossing of Jimmy Camp Creek south of the Richfield Springs ranch is strewn with these pebbles, but the bed could not be found in place.

The total thickness of the arkose has nowhere been determined. It would, in fact, necessarily be variant on account of the irregular deposition and meager horizontal extent of the material. From this irregularity it is probable that the apparently successive beds encountered in crossing the formation on a flat or gently sloping surface may be equivalent instead of consecutive. The only way to obtain reliable measurements of the beds would be by drilling at places where the formation is well exposed.

The greatest thickness measured in surface exposures of the arkose is about 200 feet in Austin Bluffs and 300 to 400 feet in Corral Bluffs. The total thickness, however, is believed to be still greater.

Gravel.—Covering all the formations near the mountains is gravel, mainly of granite débris. The boundaries of the terraces covered by the gravel have been mapped only where they cross the coal-bearing formation.

STRUCTURE.

The geologic structure of the region adjacent to the coal outcrop is very simple. From the southwesternmost point of Popes Bluff to the east end of the strip examined the strike seems to be uniformly N. 50° W., and the dip ranges from 2° to 10° NE. The most marked variation from this general structure is in the northwestern part of Popes Bluff, where, as the coal-bearing sandstone approaches the mountains, it is turned up steeply (40°–50°) and the strike is more nearly parallel to the trend of the mountains (N. 30° W.). The two most marked variations in dip are the steep dip of 10° on Jimmy Camp Creek and the flattening around Franceville.

COAL.

DETAILED SECTIONS.

The best opportunity for the study of the coal beds and of their relation to each other is afforded in Popes Bluff and adjacent exposures on the west side of Monument Creek. Numerous sections were made here, as well as at other places along the outcrop, and the most representative of these are given on the following pages. The facts shown by these sections are discussed on pages 332–335.

Sections of coal beds and coal-bearing rocks in Colorado Springs field.

[Numbers of sections correspond to those given on Pl. XVII.]

1. Monument Valley mine, sec. 11, T. 13 S., R. 67 W.

	Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie)	30	
Sandstone, ferruginous		6
Interval, mainly shale	57	
Sandstone	2	6
Interval, mainly shale.[a]		
Clay, carbonaceous } bed B		6
Coal } bed B	2	7
Coal, sandy } bed B		

2. Abandoned mine, sec. 14, T. 13 S., R. 67 W.

a. Section at mine mouth.

	Ft.	in.
Clay, pink, containing fossil plants	3	
Clay	1	
Coal } bed B	1	10
Coal, sandy } bed B	1	
Sandstone, massive.		
	3	10

b. Section 30 feet down slope.

	Ft.	in.
Clay, carbonaceous } bed B		8
Coal } bed B	2	10
Coal, sandy } bed B		
	3	6

70 feet down the slope the coal bed is 2 feet thick.

3. Popes Bluffs, sec. 14, T. 13 S., R. 67 W.

	Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie)	20	
Interval, probably shale	9	
Sand, nodular, ferruginous	2	
Interval, mainly shale	50	
Sand, containing nodular concretions of iron	1	
Shales, gray and carbonaceous	10	
Sand, with ferruginous nodules and impressions of plants	1	
Sandstone, soft, ferruginous	2	
Clay, gray	1	
Shale, carbonaceous	1	6
Sandstone, ferruginous		6

[a] Thickness not given in original notes.

	Ft.	in.
Sandstone, soft, yellow	4	
Shale, greenish	1	6
Shale, carbonaceous	3	6
Sandstone	3	
Coal		2
Shale, carbonaceous	1	
Clay, greenish	6	6
Shale, carbonaceous	1	6
Clay, sandy	3	
bed B: Shale, carbonaceous		2
bed B: Coal	2	
bed B: Coal, bony		5
bed B: Coal, sandy		5
Sandstone	19	
Conglomerate	2	
Shaly coal		6
Sandstone	1	6
Coal, sandy, bed A		7
Sandstone, gray, massive	15	
	163	9

4. Popes Bluffs, sec. 23, T. 13 S., R. 67 W.

	Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie)	15	
Interval, mainly shale	60	
Shale, carbonaceous	4	
Sandstone, argillaceous	4	6
Shale	8	
Shale, carbonaceous	1	
Sandstone	1	6
Shale, carbonaceous	3	
Coal, bed B		10
Sandstone	23	
Shale, sandy	2	6
Shale, carbonaceous		2
Sandstone	2	10
Coal, sandy, bed A	1	
Sandstone	3	
Interval, probably sandstone	12	
Sandstone, gray	18	
	160	4

5. Coal prospect on east side of Popes Bluffs, sec. 23, T. 13 S., R. 67 W.

	Ft.	in.
Sandstone	5	
Clay	4	
bed B: Coal		11
bed B: Clay and bone		8
bed B: Coal	1	6
	12	1

6. Popes Bluffs, sec. 23, T. 13 S., R. 67 W.

		Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie)		20	
Shale, gray		3	
Shale, carbonaceous		18	
Sandstone		30	
Shale, carbonaceous		12	
Sandstone, yellow, shaly		2	
Shales, light gray and brown, with coal bands 3 to 4 inches thick		45	
Sandstone, soft		2	
Shale, carbonaceous	bed B	1	6
Coal		2	6
Sand, coaly			10
Sandstone, massive, gray		25	
Shale, carbonaceous, coal, bed A (?)		4	
Sandstone, gray		1	
		166	10

7. Popes Bluffs, sec. 24, T. 13 S., R. 67 W.

		Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie)		25	
Shale, greenish		25	
Sandstone, soft, argillaceous		12	
Shale, carbonaceous		2	
Sandstone		3	
Shale, carbonaceous		5	
Shale, greenish		8	
Sandstone		3	
Shale, carbonaceous		5	
Sandstone, ferruginous			6
Shale, gray		3	6
Sandstone	bed B	15	
Coal		1	
Sand, soft, coaly		1	
Iron nodules			4
Sandstone, massive, gray		25	
Shale, brown, carbonaceous, coal, bed A(?)		3	
Shale, sandy		1	
Sandstone, gray, massive		40	
Sandstone, greenish		40	
		218	4

8. Sec. 19, T. 13 S., R. 66 W.

		Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie).			
Interval		34	
Coal		1	4
Shale		8	
Sandstone		14	
Shale, carbonaceous		2	
Sandstone and sandy shale		37	
Sandstone, massive, gray		13	
Shale, carbonaceous	bed A	1	6
Coal			3
Shale, carbonaceous			6
Coal		1	7
Shale, brown, sandy			6
Sandstone.			
		113	8

9. Sec. 19, T. 13 S., R. 66 W.

	Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie).		
Interval, mostly shale	12	
Coal	1	6
Shale and sandstone	28	
Shale	5	
Coal, bed C		11
	47	5

10. Sec. 19, T. 13 S., R. 66 W.

	Ft.	in.
Sandstone	3	
Coal		6
Shale, carbonaceous	2	1
Clay	8	
Coal (bed C)	2	6
Shale, carbonaceous (bed C)		6
Clay (bed C)		6
Sandstone, yellow	2	6
Shale, gray		1
Sandstone, soft, yellow		5
Shale, light gray with coal intrusions	3	
Sandstone, gray	16	
Coal bed B, not well exposed.		
	39	1

11. Sec. 24, T. 13 S., R. 67 W.

	Ft.	in.
Coal		6
Shale, carbonaceous	2	
Clay	1	6
Sandstone	6	
Coal (bed C)	2	4
Shale, carbonaceous (bed C)		6
Clay.		
	12	10

Below this section coal bed B is exposed with a thickness of 8 inches.

12. Mouth of prospect in sec. 24, T. 13 S., R. 67 W.

	Ft.	in.
Shale, carbonaceous (bed C)	2	6
Coal (bed C)		7
Bone (bed C)		2
Coal, bony (bed C)		5
Shale, carbonaceous (bed C)	1	2
Clay.		
	4	10

13. Sec. 24, T. 13 S., R. 67 W.

	Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie)	20	
Shale, gray	25	
Sandstone, soft	18	
Shale, gray	8	
Shale, carbonaceous	3	
Coal		2
Shale, carbonaceous	5	
Shale, gray	3	
Sandstone, massive, yellowish, gray	10	
Bone (bed C)		5
Coal (bed C)	1	10
Bone (bed C)		4

		Ft.	in.
Clay		4	
Sandstone		20	
Sandstone		25	
Shale		2	
Shale, carbonaceous		1	6
Shale, containing some coal	bed B	1	
Coal	bed B		3
Bone	bed B		3
Shale		2	
		150	9

14. Coal prospect in sec. 24, T. 13 S., R. 67 W.

		Ft.	in.
Sandstone.			
Coal, bed C			3
Shale, brown, carbonaceous		2	
Clay, green		3	
Sandstone		30	
Coal, bony	bed B		7
Clay, gray	bed B	1	5
Coal, hard, bright, conchoidal	bed B	1	1
Clay		1	11+
		40	3

The prospect slope, about 200 feet long, was driven in mostly on coal bed B, but at the end of the slope the bed is in about the same condition as where it was first struck.

15. Yards of Colorado Brick and Artificial Stone Company, sec. 19, T. 13 S., R. 66 W.

		Ft.	in.
Shale, greenish yellow		4	
Sandstone, soft, ferruginous		5	
Shale, gray, with carbonaceous and ferruginous partings		7	
Sandstone, soft, white, massive		30	
Clay		3	
Sandstone, soft, gray, massive		17	
Shale, with yellow gypsiferous sandy layer in middle		30	
Coal, bed C		1	6
Clay		1	6
Sandstone, gray, massive		35	
Shale, carbonaceous	bed B	1	6
Coal	bed B		2
Shale, carbonaceous	bed B		10
Shale			6
Sandstone, soft, yellow, with shaly layers		25	
Shale, gray		3	
Coal	bed A		6
Coal, sandy	bed A		9
Sandstone.			
		166	3

16. West bluff along which road runs, sec. 19, T. 13 S., R. 66 W.

		Ft.	in.
Sandstone.			
Coal, including about 2 inches of bone near middle	bed B		11
Shale, carbonaceous	bed B	3	
Sandstone		26	
Coal, bed A (?)		2	6
Shale, brown.			
		32	5

Coal bed A varies from 1 foot 10 inches to 3 feet in thickness.

17. Coal beds in upper part of formation in sec. 14, T. 13 S., R. 67 W.

	Ft.	in.
Limonite, concretionary	2	
Shale, with limonite concretions	20	
Sandstone	1	6
Shale (?)	10	
Shale, greenish gray	5	
Shale, carbonaceous	3	
Coal	2	2
Shale, carbonaceous	5	
Sandstone		5
Shale (?)	5	
Shale, sandy	5	
Shale (?)	6	
Sandstone, gray	10	
Sandstone, ferruginous	1	6
Sandstone, cross-bedded	20	
Sandstone, massive	25	
Sandstone, argillaceous	5	
Sandstone, ferruginous	2	6
Shale	8	
Sandstone	18	
	155	1

18. Air shaft of Neer mine, sec. 13, T. 13 S., R. 67 W.

	Ft.	in.
Sandstone, massive	100	
Clay, sandy	2	2
Coal, bed C (?)		½
Shale, carbonaceous	1	6
Clay, sandy	35	
Sandstone, with coal bands, coal bed B (?)	2	
Sandstone, massive	30	
Coal, bed A	3	
Coal bed A is the one worked in this mine.	173	8½

19. Coal prospect in sec. 19, T. 13 S., R. 66 W.

	Ft.	in.
Sandstone, massive	13	
Shale, carbonaceous with coal lenses (bed B)		3
Coal (bed B)		7
Bone (bed B)		10
Clay	25	
Coal, bed A.		
	39	8

20. Upper part of coal-bearing formation west of Carlton mine, NE. ¼ sec. 13, T. 13 S., R. 67 W.

	Ft.	in.
Shale, gray		6
Coal	1	4
Shale, carbonaceous	1	
Clay, gray	1	
Shale, gray (?)	12	
Shale, carbonaceous with traces of coal		6
Coal	1	
Shale, carbonaceous	1	

	Ft.	in.
Clay, gray	2	
Coal		7
Shale, carbonaceous	3	
	23	11

The middle coal bed in this section varies from 6 to 18 inches within a horizontal distance of 20 feet. The coal beds are probably lenticular and irregular, as they do not show in the section back of the Carlton mine.

21. Carlton mine, sec. 18, T. 13 S., R. 66 W.

		Ft.	in.
Sandstone, soft.			
Coal, laminated and bony, with 2 inches of sandstone near base	bed A		10
Coal	bed A	3	2
Coal, "siliceous," bony	bed A	1	
Coal	bed A	3	8
Coal, bony	bed A		5
		9	1

22. West side of Pulpit Rock, sec. 17, T. 13 S., R. 66 W.

	Ft.	in.
Arkose.		
Clay, gray		6
Sandstone, gray (fossils)	4	
Shale, gray	1	6
Clay, purplish brown	2	
Shale, carbonaceous, and gray sandstone	8	
Sandstone, argillaceous	8	
Clay, brownish gray (fossils)	2	
Sandstone, quartzose	7	
Shale, carbonaceous	1	
Tuffs, gray and greenish yellow, with carbonaceous shale	65	
Conglomerate with pebbles of andesite	18	
Tuffs, gray and greenish yellow, with carbonaceous shale	46	
Interval, probably composed of tuff	15	
Clay and argillaceous sand (fossils)	125	
Sandstone, soft, white, with carbonaceous bands	50	
Sandstone, massive, yellow	3	
Clay, sandy	2	
Sandstone, argillaceous	2	
Clay, gray, sandy	3	
Clay, gray	1	6
Coal and clay, interlaminated		8
Clay, gray, sandy	5	
	370	2

The thicknesses given in this section are only approximate, as the dips are slight and the section was measured along a gently inclined surface.

23. East bank of Monument Creek, opposite old Williams mine, sec. 19, T. 13 S., R. 66 W.

		Ft.	in.
Sandstone, massive, yellow.			
Shale		15	
Shale, carbonaceous	bed A		6
Bone	bed A		5
Coal	bed A	1	
Coal, impure	bed A	1	2
Shale, carbonaceous	bed A	1	2
Clay, greenish gray.			
		19	3

24. Gully on east bank of Monument Creek east of Pikeview station, sec. 19, T. 13 S., R. 66 W.

		Ft.	in.
Sandstone, soft, white		5	
Coal, sandy			2
Clay, sandy		3	
Interval concealed		2	
Sandstone, massive		15	
Clay, sandy		13	
Shale, carbonaceous			3
Clay, sandy			6
Shale, green		20	
Shale, carbonaceous	bed C (?)	2	
Coal	bed C (?)		10
Shale, carbonaceous	bed C (?)	1	4
Shale, green		2	
Interval, probably shale		3	
Sandstone, massive		17	
Coal	bed B		6
Shale, carbonaceous	bed B	1	
Sandstone		23	
Shale, mostly carbonaceous	bed A	6	
Coal	bed A	4	
Shale, carbonaceous	bed A	1(?)	
Coal	bed A		3
Clay		3	1
Shale, greenish		6	
Bone			1
Shale, carbonaceous		2	5
Bone			4
Coal, bed A		1	2
Sandstone		46	
		176	3

27. Curtis mine, sec. 29, T. 13 S., R. 66 W.

		Ft.	in.
Shale		3	
Shale, sand, and clay		5	
Sandstone, massive		13	
Shale			6
Clay, gray			9
Bone	bed A		8
Bone, with layers of coal	bed A	2	2
Coal, bony	bed A	1	6
Coal	bed A	12	9
Clay.			
		39	4

32. Sec. 12, T. 14 S., R. 66 W.

		Ft.	in.
Shale, carbonaceous, resembling coal; probably represents a coal bed			5
Shale, in places sandy		4	
Sandstone, massive, soft, ferruginous		1	6
Shale, sandy in upper part		4	
Clay, sandy			3
Shale, carbonaceous	bed A (?)		3
Coal	bed A (?)		10
Shale, carbonaceous	bed A (?)	1	

	Ft.	in.
Sandstone, massive, argillaceous	3	6
Shale, dark gray	4	
Sandstone, ferruginous	2	4
Sandstone, soft, yellow, fine grained, quartzose	11	
Shale, gray	2	4
Shale, sandy, ferruginous	2	4
Sandstone	40	
	77	9

33. Sec. 19, T. 14 S., R. 64 W.

	Ft.	in
Coal, not fully exposed, bed B.		
Shale, yellow, sandy	1	6
Sandstone	1	10
Shale, gray	3	
Sandstone	2	6
Clay and shale (fossils)	4	
Coal, bottom not exposed, bed A	7	
	19	10

35. Davies mine, sec. 29, T. 14 S., R. 64 W.

	Ft.	in.
Coal, bony		5
Shale, carbonaceous		6
Clay	2	
Sandstone, yellow, massive	10	
Clay, carbonaceous		3
Coal	1	
Bone		5
Clay, gray	5	
Coal (bed A)	1	1
Coal, bony (bed A)	1	3
Coal (bed A)	2	4
Clay		2
	24	5

36. Stream bank in SE. ¼ sec. 32, T. 14 S., R. 64 W.

	Ft.	in.
Coal		4
Shale, sandy	15	
Coal		4
Shale, sandy	20	
Sandstone, soft, gray	2	
Clay, gray		6
Shale	1	
Coal	1	2
Shale, carbonaceous	2+	
	42	4+

37. Along stream channel just south of Banties ranch, sec. 20, T. 15 S., R. 63 W.

	Ft.	in.
Sandstone.		
Clay, carbonaceous		3
Shale, gray		8
Coal	1	
Clay, gray		½
Sandstone	5	
Shale, gray	5	
	11	11½

38. Jimmy Camp Creek; upper part measured due east from Richfield Springs ranch and lower part in sec. 15, T. 14 S., R. 65 W.

	Ft.	in.
1. Sandstone, soft, argillaceous (fossils)	1	
2. Sandstone, massive, cross-bedded, tuffaceous	10	
3. Shale, gray	1	
4. Shale, carbonaceous	1	
5. Shale, gray	5	6
6. Shale, gray, and yellow sandstone	102	
7. Shale, carbonaceous		2
8. Shale, gray		4
9. Shale, carbonaceous		½
9½. Coal		½
10. Clay		½
11. Coal		4½
12. Interval, covered	550	
13. Arkose, quartz and feldspar	3	
14. Concealed	90	
15. Shale, sandy, yellow	37	
16. Shale, carbonaceous	1	
17. Tuff	41	
18. Shale, containing some coal		4
19. Tuff	5	
20. Shale, black, carbonaceous	1	
21. Tuff	20	
22. Sandstone, ferruginous (fossils)		10
23. Tuff	11	6
24. Tuffs, yellow and purple	7	
25. Shale	33	
26. Sandstone, ferruginous	2	
27. Shale	14	
28. Sandstone, massive, soft, argillaceous	4	6
29. Shale, yellow and dark gray	22	
30. Sandstone, calcareous	2	
31. Shale	4	
32. Sandstone, soft	27	
33. Shale, with ferruginous layers	2	
34. Sandstone, soft	2	4
35. Shale, sandy	7	
36. Interval, not measurable on account of local increase of dip and change of strike; estimated	10	
37. Shale, carbonaceous		10
38. Coal	2	4
39. Concealed	36	
40. Sandstone, ferruginous	2	
41. Shale	2	
42. Shale, carbonaceous		10
43. Shale, green	17	6
44. Sandstone	4	6
45. Shale, carbonaceous	1	6
46. Clay	1	
47. Coal, bed A (?), burned and underlain by coaly sandstone	6	
48. Sandstone, shaly	8	

	Ft.	in.
49. Sandstone, gray, massive	24	
50. Sandstone, gray, ferruginous	6	
51. Sandstone	4	
52. Sandstone, soft, gray, quartzose	27	
53. Interval, not measurable but estimated	25	
54. Conglomerate, ferruginous	2	
55. Shale, gray	2	
56. Conglomerate, ferruginous	2	
57. Sandstone, concretionary	20	
58. Sandstone, soft (fossils)	25	
59. Sandstone, soft, yellow	25	
60. Shale, light gray.		
	1, 263	6

From an inspection of these sections it is evident that there are three more or less well defined coal beds. These have been lettered, beginning at the bottom, A, B, and C. Bed A, which is the principal bed, is not well developed west of Monument Creek. At the most easterly of these places (section 15), the coal shows its greatest thickness of 1 foot 3 inches. There seems to be little doubt, however, from its position in the section that the carbonaceous shale and coaly sand shown in many sections and marked coal A is the impure marginal portion of the coal bed.

The outcrop of coal bed B where it is 2 feet or more thick is shown on the map (Pl. XVII) and its position in the column is indicated in several sections. That the coal which has been prospected and developed along the west face of Pikeview Bluffs is bed B and not bed A seems evident from its position in the sections—from its relation, for instance, to the topmost of the three sandstones that are so well developed in this part of the field.

Although the map shows that a third bed, called coal C, reaches a thickness of 2 feet or more over a small extent of its outcrop in the area of the bluffs under discussion, yet it may be seen from the sections that it is not a persistent bed but rather a local development of coal at different horizons within a shaly band of varying thickness lying between the middle and upper beds of sandstone.

There is little reason to expect that individual coal and sandstone beds in this section could be correlated with sandstone and coal beds in the vicinity of Denver; yet, as a matter of fact, the similarity between the coal-bearing rocks in the two fields is remarkable. Thus, in the western part of the Colorado Springs field and in the Denver field there is "a series of basal sandstones up to 200 feet in thickness."[a] Above this series in both fields occurs an argillaceous formation, but in the Denver field this is 400 to 1,000 feet thick, whereas in the Colorado Springs field it is only about 150 feet thick. In both fields the sandstone is divisible into three beds with intermediate beds of coal and shale. The similarity is shown in figure 3.

[a] Emmons, S. F., Mon. U. S. Geol. Survey, vol. 27, 1896, p. 28.

Between the place where section 7 was measured and Monument Creek a workable though varying thickness of coal outcrops in the banks of the streams. There is no means of determining which coal bed is worked in the Carlton mine, but from the more extensive development of coal A it is believed to be that bed. If this interpretation is correct, however, the thickening is local, for along Monument Creek to the south bed A, as shown in section 6, contains little coal. Coal bed A is of workable thickness in the Williamsville mine, expands to a maximum of 14 feet in and near the Curtis mine, and, according to report, thins to less than 3 feet in the Enterprise mine.

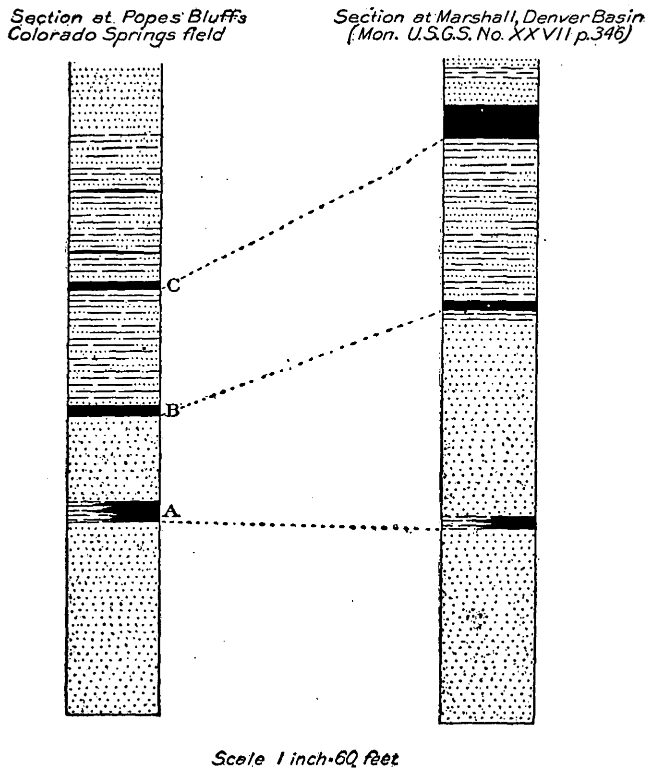


FIGURE 3.—Sections showing similarity in the arrangement of the coal-bearing part of the Laramie formation in the Colorado Springs field and in the Denver Basin.

Coal sections 25 to 31 (Williamsville to Tudor) show in greater detail the variations in this coal bed. A bed of impure coaly material about a foot thick at both ends of this thick body of coal is well brought out in these sections. In places this bed is almost pure clay and attains a thickness of 2 feet, but benches of coal about 3 feet thick remain above and below it. It is well to bear this in mind in developing the coal of this region and to test occasionally with drill holes through the roof and floor for overlying or underlying benches of coal.

From an exposure on Sand Creek about half a mile southeast of the Enterprise mine (section 32) to the bluffs on Jimmy Camp Creek no exposure of coal could be found, as the rocks are nearly covered by soil. On Jimmy Camp Creek most of the coal along the outcrop has been burned. From records of the old McFerran mine, however, the coal bed is known to have averaged about 6 feet in thickness. A few hundred feet south of the road on the east bank of the creek, in sec. 18, T. 14 S., R. 65 W., an upper coal bed shows but is not well exposed. Here 2 feet 4 inches of coal was measured without reaching the bottom. This bed is about 65 feet above coal bed A and is therefore in the position of coal bed C.

In secs. 14 and 15, T. 14 S., R. 65 W., there are numerous exposures of coal. Farther east, however, little evidence of the coal bed can be seen until the old Franceville slope is reached, and the first good section of it is found in the creek bank just north of the highway bridge at the west edge of sec. 19, T. 14 S., R. 64 W. Here 7 feet of coal is exposed without showing the bottom. Coal section 35 represents the coal bed in the Davies mine and shows that the coal here is thinner. In sec. 32, T. 14 S., R. 64 W., the coal bed is thinner still and where the outcrop crosses the east line of sec. 5, T. 15 S., R. 64 W., the coal has probably a thickness of only a few inches. More noteworthy than the outcrop of coal A in this strip is the occurrence of a group of upper coal beds (perhaps coal C) in the creek in the NE. ¼ sec. 5. From this point to the east end of the field the only exposure of coal that could be found is a bed 1 foot thick in sec. 20, T. 15 S., R. 63 W. (See section 37.) On Black Squirrel Creek south of Crows Roost ranch the beds at the horizon of the coal are fairly well exposed, yet no trace of a coal bed could be found. It seems probable, therefore, that along the outcrop in T. 15 S., Rs. 62, 63, and 64 W., there is no workable coal.

Coal in the shaly member of the Laramie is known in only two places in the field, both near the west end, in secs. 13 and 14, T. 13 S., R. 67 W. (See sections 17 and 20.) At both places the coal has been prospected but the openings are caved. The coal appears bright and clean, but the beds are of varying thickness and apparently of slight horizontal extent. On account of soil covering it was not possible to determine whether the two outcrops are connected.

In this connection Emmons's comment on the coals of the shaly Laramie in the Denver Basin may be noted.[a] "Coal seams have also been found in the upper clayey division, but the coals are lignites [subbituminous in the present classification], with higher percentages of water and of inferior economic value."

Coaly shale occurs in the formation next above the Laramie, but so far as known the thickness of the coal beds in this formation is so small as to make them entirely negligible.

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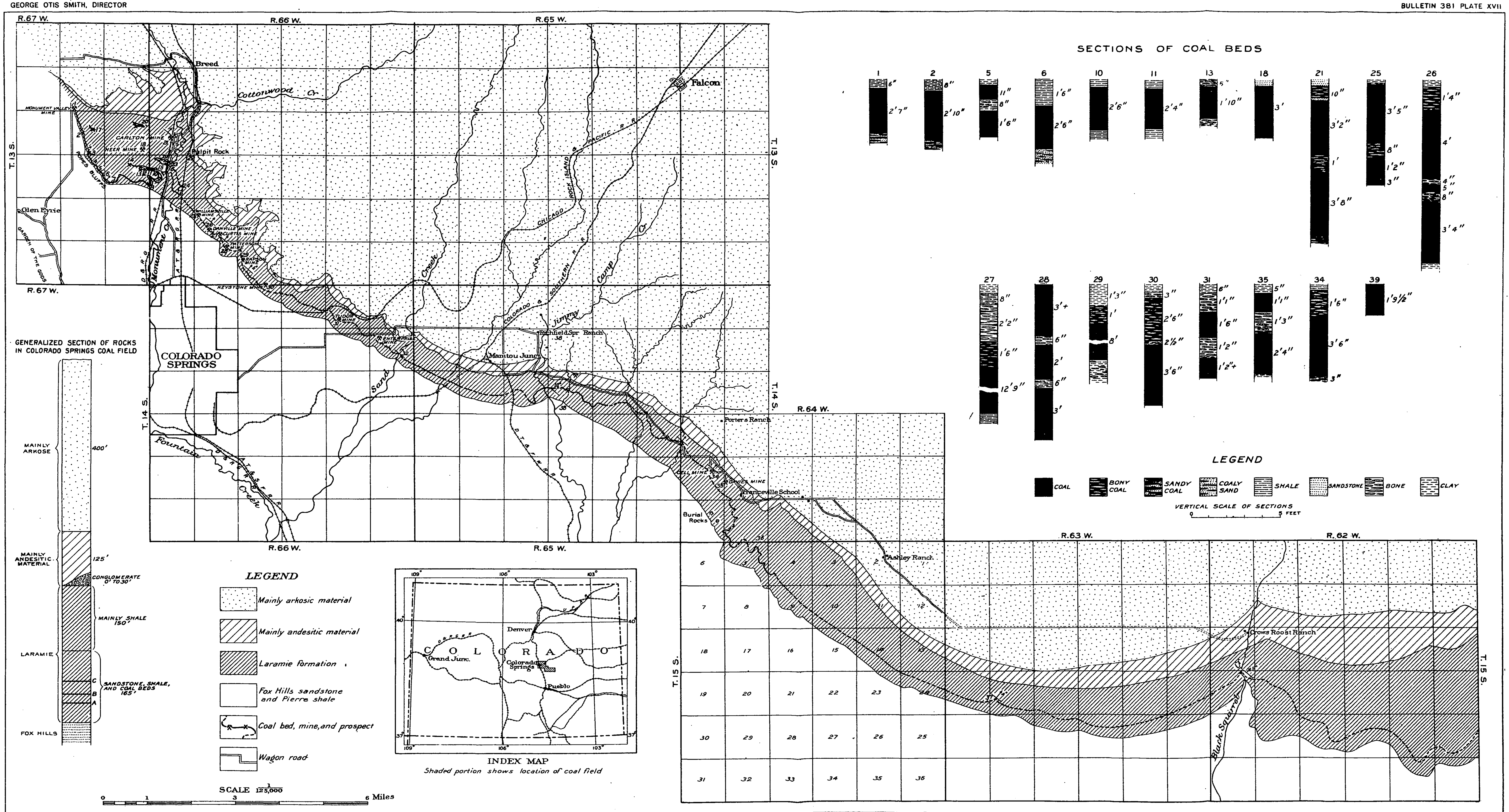
[a] Emmons, S. F., Mon. U. S. Geol. Survey, vol. 27, 1896, p. 29.



MAP OF COLORADO SPRINGS COAL FIELD, EL PASO COUNTY, COLORADO

By Marcus I. Goldman

House Doc. No. 1536; 60th Cong., 2d Sess.

In the andesitic beds dark-brown shale full of leaf fragments is found and here and there it contains some coal. This is shown in section 38 from No. 14 to No. 24, inclusive.

Above this, in the arkosic rocks along the east bank of Jimmy Camp Creek, east and a little southeast from the Richfield Springs ranch, several small coal beds occur as shown in section 38 from No. 2 to No. 12, inclusive.

These sections show no coal of any practical importance, nor were prospects on coals in the arkosic or andesitic beds found in the part of the field represented in the accompanying map. The thickest bed of coal in the upper formations, as reported in well records, is 10 inches thick, but recently thick beds have been reported several miles north and east of Falcon.

The following list gives the location of the places where sections were measured and samples taken for analysis. The numbers correspond to those of the sections given above and also to those used on Plate XVII.

1. Monument Valley mine, sec. 11, T. 13 S., R. 67 W. Coal bed B; analysis No. 6545. Sample taken on south wall of slope 20 feet from mouth. Coal dry, but probably weathered.

2. Abandoned prospect, sec. 14, T. 13 S., R. 67 W. Coal bed B.

5. East side of Popes Bluffs, sec. 23, T. 13 S., R. 67 W. Coal bed B.

6. Popes Bluffs, sec. 23, T. 13 S., R. 67 W. Coal bed B.

10. Prospect in sec. 19, T. 13 S., R. 66 W. Coal bed C.

11. Prospect in SE. ¼ NE. ¼ sec. 24, T. 13 S., R. 67 W. Coal bed C; analysis No. 7129. This prospect had not been operated recently and coal is probably weathered.

13. Sec. 24, T. 13 S., R. 67 W. Coal bed C.

18. Neer mine, sec. 13, T. 13 S., R. 67 W. Coal bed A; analysis No. 6439. Sample obtained in main entry 130 feet south of foot of shaft.

21. Carlton mine, sec. 18, T. 13 S., R. 66 W. Coal bed A; analysis No. 6443. Sample taken from face of room 19 off thirteenth entry.

25. Williamsville mine, sec. 29, T. 13 S., R. 66 W. Coal bed A.

26. Danville mine, sec. 29, T. 13 S., R. 66 W. Coal bed A; analysis No. 6442. Sample taken from main slope beyond ninth entry.

27. Curtis mine, sec. 29, T. 13 S., R. 66 W. Coal bed A; analysis No. 6440. Sample taken from back entry off seventh north entry and represents 6 feet 10 inches of the lower bench.

28. Patterson mine, sec. 32, T. 13 S., R. 66 W. Coal bed A.

29. Rapson mine, sec. 33, T. 13 S., R. 66 W. Coal bed A; analysis No. 6441. Sample taken from third room off fourth south entry and represents 5 feet 9 inches of the main bench.

30. Keystone mine, sec. 4, T. 14 S., R. 66 W. Coal bed A; analysis No. 6546. Sample taken in crosscut being driven as an airway to old workings 50 feet south of main entry and 800 feet from foot of shaft.

31. Tudor mine, abandoned slope, sec. 2, T. 14 S., R. 66 W. Coal bed ?.

34. Cell mine, sec. 30, T. 14 S., R. 64 W. Coal bed A; analysis No. 6438. Sample taken at a point 1,050 feet northeast of mouth of slope.

35. Davies mine, sec. 29, T. 14 S., R. 64 W. Coal bed A; analysis No. 6437. Sample taken at a point 425 feet northeast of mouth of main slope.

38. Purdon prospect (not in area represented by the map), SE. ¼ NW. ¼ sec. 27, T. 11 S., R. 61 W. Coal bed ?. Analysis No. 7128.

CHARACTER OF THE COAL.

There is no marked difference in the character of the coal in different parts of this field. In general, it is a lustrous black, rather homogeneous coal with conchoidal fracture. On close inspection it is seen to be less homogeneous than appears at first sight, for it is composed of lenses up to a few feet long, and from a small fraction of an inch up to several inches thick, of a brilliant glossy black coal, showing in many places the woody structure of the material from which it was derived, in a matrix of a dull black, more granular material. The coal slacks readily on exposure to circulating air, breaking into fragments along an irregular network of cracks. Fossil resin is common in the coal.

The following analyses were made at the Pittsburg laboratory of the United States Geological Survey on samples collected during the present examination. Each sample was obtained by making a cut across a face of the coal bed, including such parts as were mined or could be mined to advantage. The descriptions on page 335 show the part of the bed that is represented by the sample. Owing to the fact that not many mines were in operation, some of the samples were taken from old prospect entries, and in such places the coal was doubtless weathered, although all coal showing effects of weathering was carefully removed before sampling was begun. In the active mines the coal was fresh, having been taken from a recently worked face.

Analyses of coal samples from the Colorado Springs coal field, Colorado.

[F. M. Stanton, chemist in charge.]

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T. S.	R. W.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
					Ft. in.	Ft. in.													
6545	SW. ¼	11	13	67	2 7	2 7	11.4	As received	20.2	35.1	37.6	7.09	1.03	5.74	51.64	0.58	33.92	4,857	8,743
								Air dried	9.9	39.6	42.5	8.00	1.16	5.04	58.29	.65	26.86	5,482	9,868
								Dry coal		44.0	47.1	8.88	1.29	4.38	64.66	.73	20.06	6,082	10,948
								Pure coal a		48.3	51.7		1.42	4.81	70.96	.80	22.01	6,675	12,015
6439		13	13	67	4 7	4 7	17.4	As received	22.2	34.6	37.4	5.8	.47					4,724	8,503
								Air dried	5.8	41.9	45.2	7.1	.57					5,719	10,294
								Dry coal		44.4	48.1	7.5	.60					6,071	10,928
								Pure coal		48.0	52.0		.65					6,563	11,813
6443		18	13	66	8 7	6 10	15.3	As received	25.5	31.6	38.1	4.8	.25					4,614	8,305
								Air dried	12.1	37.3	44.9	5.7	.30					5,448	9,806
								Dry coal		42.4	51.1	6.5	.34					6,195	11,151
								Pure coal		45.3	54.7		.36					6,626	11,927
6442		29	13	66	8 10	6 5	15.4	As received	21.8	33.6	37.9	6.7	.40					4,735	8,523
								Air dried	7.6	39.7	44.8	7.9	.47					5,597	10,075
								Dry coal		43.0	48.5	8.5	.51					6,055	10,899
								Pure coal		47.0	53.0		.56					6,620	11,916
6440		29	13	66	12 9	6 10	15.6	As received	20.9	33.7	39.9	5.53	.39	6.05	52.25	.69	35.09	4,951	8,912
								Air dried	6.3	39.9	47.2	6.55	.46	5.12	61.91	.82	25.14	5,866	10,559
								Dry coal		42.6	50.4	6.99	.49	4.72	66.07	.87	20.86	6,261	11,270
								Pure coal		45.8	54.2		.53	5.07	71.04	.94	22.42	6,732	12,118
6441		33	13	66	8	5 9	14.6	As received	19.9	34.3	38.3	7.5	.37					4,802	8,643
								Air dried	6.2	40.1	44.9	8.8	.43					5,623	10,121
								Dry coal		42.8	47.9	9.3	.46					5,995	10,791
								Pure coal		47.2	52.8		.51					6,613	11,903
6546	NE. ¼	4	14	66	5 7	5 7	16.9	As received	25.6	30.2	38.6	5.57	.42	6.32	51.69	.71	35.29	4,848	8,726
								Air dried	10.5	36.3	46.5	6.70	.50	5.34	62.21	.85	24.40	5,834	10,501
								Dry coal		40.6	51.9	7.49	.56	4.67	69.51	.95	16.82	6,520	11,736
								Pure coal		43.9	56.1		.61	5.05	75.14	1.03	18.17	7,048	12,686

Analyses of coal samples from the Colorado Springs coal field, Colorado—Continued.

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate				Ultimate.					Heat value.	
	Quarter.	Sec.	T. S.	R. W.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
					Ft. in.	*Ft. in.*													
6438	....	30	14	64	4 7	3 6	14.5	As received.....	19.2	32.4	41.4	7.02	0.45	5.79	53.63	0.86	32.25	5,170	9,306
								Air dried.......	5.5	37.8	48.5	8.21	.53	4.89	62.73	1.01	22.63	6,047	10,885
								Dry coal........	....	40.0	51.3	8.69	.56	4.52	66.40	1.06	18.77	6,401	11,522
								Pure coal.......	....	43.8	56.2	....	.61	4.95	72.72	1.16	20.56	7,010	12,628
6437	....	29	14	64	4 8	3 5	18.0	As received.....	22.1	32.5	38.9	6.5	.48	....	....	....	....	5,631	10,136
								Air dried.......	5.0	39.6	47.4	8.0	.58	....	....	....	....	6,121	11,018
								Dry coal........	....	41.7	49.9	8.4	.62	....	....	....	....	7,230	13,014
								Pure coal.......	....	45.5	54.5	....	.68	....	....	....	....	7,893	14,207
7129	SE. ¼ NE. ¼	24	13	67	2 4	2 4	14.5	As received.....	23.1	31.2	35.6	10.13	.21	5.77	47.69	.64	35.56	4,461	8,030
								Air dried.......	10.0	36.5	41.6	11.85	.25	4.86	55.78	.75	26.51	5,218	9,392
								Dry coal........	....	40.5	46.3	13.17	.27	4.17	61.99	.83	19.57	5,799	10,438
								Pure coal.......	....	46.7	53.3	....	.31	4.80	71.39	.96	22.54	6,779	12,022
7128	SE. ¼ NW. ¼	27	11	61	1 9½	1 9½	26.4	As received.....	34.4	24.4	27.3	13.89	.14	6.46	35.94	.66	42.91	3,364	6,055
								Air dried.......	10.9	33.2	37.0	18.87	.19	4.80	48.83	.89	26.42	4,571	8,228
								Dry coal........	....	37.2	41.6	21.17	.21	4.02	54.79	1.01	18.80	5,128	9,230
								Pure coal.......	....	47.3	52.7	....	.27	5.10	69.51	1.28	23.84	6,505	11,709

[a] "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated, but owing to the briefness and convenience of the term, it is used in this report as noted above.

DEVELOPMENT AND MARKETS.

A brief review of the history of mining in the region, gathered from reports such as those of the state coal-mine inspector of Colorado and from the Mineral Resources volumes published by the United States Geological Survey, is given below.

In the first volume of Mineral Resources[a] occurs this statement concerning El Paso County:

The only mines worked to any extent are those owned by the Denver and New Orleans Railroad Company at Franceville * * *. The product has only become available since the completion of the Denver and New Orleans Railroad in July, 1882.

That coal was taken out for local use before that time is quite possible, but it is impossible to trace the history of such small-scale working of coal seams by any authentic records; very likely such operations began with the earliest settlement of the region.

The Franceville mine was operated from the middle of 1882, apparently, till 1898, which is the last year for which its production is reported by the state inspector of coal mines. During that period it produced the following annual amounts:

Production of Franceville coal mine, 1882–1898.

	Short tons.		Short tons.
1882	23,689	1891	1,064
1883	54,416	1892	26,000
1884	56,070	1893	10,000
1885	39,038	1894	No report.
1886	50,000	1895	7,943
1887	47,017	1896	16,413
1888	39,144	1897	15,517
1889	27,926	1898	10,409
1890	9,335		

The McFerran mine commenced producing in November, 1888.[b] In 1896 it was abandoned and the inspector says:[c] "It appears that the mine has never been on a paying basis." A table of its production follows:

Production of McFerran coal mine, 1888–1896.

	Short tons.		Short tons.
1888	5,000	1893	19,318
1889	26,140	1894	No report.
1890	17,512	1895	41,995
1891	33,300	1896	8,424
1892	9,788		

Until 1896 the McFerran and Franceville mines were the only ones reported for El Paso County by the state inspector. About that year, apparently, several small mines were opened in the west end of

[a] Mineral Resources U. S. for 1882, U. S. Geol. Survey, 1883, p. 39.
[b] Third Bienn. Rept. Colorado State Coal-Mine Insp., p. 104.
[c] Seventh Bienn. Rept. Colorado State Coal-Mine Insp., p. 36.

the field—that is, north of Colorado Springs—only to be abandoned within the next year or two. Of the present larger mines north of the town the Carlton or Pikeview was the first to be opened. Shaft sinking was begun in the latter part of 1896 and the main coal was struck January 1, 1897.[a]

The Curtis, Danville, and Williamsville mines followed within the next year, and others, some of them now abandoned, were opened from time to time thereafter.

The principal developments at present are the group of mines about 2 miles north of Colorado Springs. Of these only the Curtis and Rapson have shafts, the others being slope mines. The room and pillar method of extracting the coal is used entirely, with pillars about 18 feet thick and rooms about 22 feet wide. Some coal is almost always left in the roof because the rock overlying the coal is in most places a very weak sandy clay. As the coal in these mines is of good quality and abundant to meet present demands, there has been no effort to develop the deeper-lying portions of the bed. The depth of the Carlton or Pikeview shaft, the deepest in the field, is 175 feet.

The Neer mine is also opened by a shaft and is working on about 3 feet of coal believed to be coal A.

On coal B the only mine now operating is the Monument Valley, in the SW. ¼ sec. 11, T. 13 S., R. 67 W., near the south line of the section. This mine differs from all the others in that the bed dips steeply, and hence the slope starts directly on the coal. It was reopened so near the end of the field season that there was no time to examine the deeper workings. At the mouth of the slope the coal is about 3 feet thick; in depth, 4 feet of it is reported.

The only mines operating farther east are the Cell, or new Franceville, and the Davies mine, in the southwestern part of T. 14 S., R. 64 W. Both of these are slope mines with about 3½ to 4 feet of coal.

The coal of the Colorado Springs field is used largely for domestic purposes. It seems in addition to be very satisfactory for burning under boilers, as it is applied in this way by such plants as those of the Colorado Springs Electric Company and the mills in Colorado City and at Cripple Creek. The mines at Franceville supply a wagon trade entirely, for use mainly by creameries and ranches.

Any part of the field can be easily entered by a railroad; in fact, there were branches to the old Franceville and McFerran mines while they were still operating.

[a] Eighth Bienn. Rept. Colorado State Coal-Mine Insp., p. 74.

THE CANON CITY COAL FIELD, COLORADO.

By Chester W. Washburne.

INTRODUCTION.

The Canon City coal field is located on the east front of the Rocky Mountains in south-central Colorado. It is one of the earliest developed coal fields of the State and is one of the best known, producing a high-grade, clean, dry domestic fuel.

The following paper sums up briefly the principal results of a reconnaissance examination made in the summer of 1908. Many of the east-west section lines were traversed on foot, distance being determined by pacing and points located by compass intersections. The outcrops of the coal beds were meandered in the same way, and sections of the beds were made in the mines and prospects, it being impossible to measure the coal elsewhere. The original purpose of the work was land classification, and when it was ascertained that no coal land remained in possession of the Government no attempt was made to dig into the weathered outcrops to measure the coal beds, and only such data were gathered as seemed most useful to those engaged in prospecting or developing the field. No attempt was made to sketch the topography. The more detailed results of this work will be presented in a later publication.

TOPOGRAPHY.

The Canon City coal field occupies a small mesa at the foot of Wet Mountain and west of a broad valley of Pierre shale, in which lies the Florence oil field. The mesa rises gradually westward in smooth grassy plains that merge with Wet Mountain in the southern part of the coal field. In the northern part of the field there is a depression in the mesa, known as Wolf Park, west of which is a sharp ridge of the upturned sandstone of the Laramie formation separating this park from the shale valley that lies at the foot of Wet Mountain. The north and east sides of the coal field are marked by a series of high cliffs characterized by projecting points and deep reentrants. The latter were cut by small creeks, most of which are intermittent in flow, but Newland, Oak, and Chandler creeks, which rise in Wet Mountain, carry a perennial flow across the coal field.

Small pine and oak trees grow over most of the northern part of the mesa and along the stream courses in the southern part. These are not suitable for mine timber, and consequently material for this purpose must either be hauled by wagon from Wet Mountain or shipped by rail from distant places. There is a good growth of grass on the mesa which is green for the greater part of the year. The principal wagon roads across the field follow the sharp canyons. Elsewhere travel is difficult, owing to the abundance of small gullies and cliffs.

Spurs from the Denver and Rio Grande and the Atchison, Topeka and Santa Fe railroads reach all the principal mines in the northern and eastern parts of the field. The southwestern part has no railroad connection and therefore no important mines.

GENERAL GEOLOGY.

STRUCTURE.

Throughout the greater part of the coal field the strata dip gently westward at angles varying from 2° to 5°. Along the western margin the strata are sharply upturned, probably from the influence of a thrust fault at the foot of Wet Mountain. This fault cuts across the coal measures in the southern part of the field and is marked by a complete overturn of the beds in that locality. (See Pl. XVIII.) The coal beds are there overlain by granite which has been thrust upon them. On tracing the coal beds northward from the granite contact they are seen to be overturned, having westward dips of about 45° for a distance of over a mile; farther north they are upright for several miles and acquire progressively lower eastward dips as they leave the influence of the Wet Mountain fault. At the northwest end of the field, where, owing to its distance, the influence of the fault is slight, the dips are only 12° to 20°. The structural features are best shown by the dip symbols on the accompanying map (Pl. XVIII).

STRATIGRAPHY.

The coal beds of the Canon City field occur in the Laramie formation. Beneath the Laramie is the Trinidad sandstone, which rests on Pierre shale. Various Mesozoic and Paleozoic strata lie between the Pierre shale and the Archean granite, but these have no economic bearing on the coal field and therefore will not be described in this paper. Above the Laramie is conglomerate, probably equivalent to the Arapahoe conglomerate of the Denver Basin and the Poison Canyon formation of the Trinidad field. A small remnant of tuffaceous sandstone and shale, probably corresponding with a part of the Denver formation, rests at one locality on the Arapahoe (?) conglomerate.

PIERRE SHALE.

The Pierre shale is a remarkably uniform body of consolidated sea mud, soft dark gray to greenish black at the surface of the ground. The fresh unweathered shale is firm and readily fissile along the bedding planes, as shown by the flat platy character of the drillings from oil wells. Considerable bodies of it are almost white, although dark-gray to bluish-black colors prevail. It contains numerous large, hard calcareous concretions, a few of which make "tepee buttes" on the low plains north and east of the coal field. Small hard, brittle ferrocalcareous concretions are abundant at certain horizons. In grading a street in the western part of Florence a bed of bluish-white limestone, about 2 inches thick, was observed, but this is the only occurrence of limestone in the upper part of the Pierre shale observed in this region. Near the base of the shale are a few nonpersistent beds of very impure limestone 1 to 8 inches thick. Beds of sandstone 6 inches to 3 feet thick are common in the upper 300 feet, and in this zone there are in most sections one or two beds of resistant sandstone 5 to 10 feet thick. A few thin beds of sandstone are found as far as 700 feet below the top of the Pierre, but there are none below that horizon. As the base of the overlying Trinidad sandstone is approached, sand and clay become equally important constituents of the section and are distributed in a peculiar and interesting way. Beds of sandstone 4 to 8 inches thick alternate with beds of shale 2 to 6 inches thick, through a distance of 30 to 50 feet below the base of the Trinidad sandstone. This regular alternation of coarse and fine sediment is suggestive of the work of periodic floods alternating with slower currents at the mouth of a river. At one locality fifty-two of these beds of sandstone separated by partings of shale were counted in a section 45 feet thick. The beds contain no fossils on the east side of the field, but on the west side the leaves of deciduous plants are abundant in both the sandstone and the shale. At different horizons in the underlying shale are found many marine Upper Cretaceous bivalves and ammonites.

TRINIDAD SANDSTONE.

The Trinidad sandstone is a massive, yellow-weathering sandstone, thin bedded near the base, where it grades imperceptibly into the Pierre shale. Layers of clay become increasingly abundant toward the bottom of the sandstone, and in the upper part of the shale layers of sandstone become increasingly abundant toward the top. The boundary between the two is uncertain, and the base of the former in the Canon City field may not correspond exactly with the base of the Trinidad sandstone in the Trinidad field. In the latter locality the top of the Pierre shale contains invertebrate fossils of the same types as those found at the same horizon near Canon City. Moreover, the name Trinidad sandstone is now well established in this field, because both geologists and miners have observed the lithologic similarity between the sandstone at the base of the coal-bearing strata at Trinidad and the sandstone at the base of the coal-bearing strata of the Canon City field. The continued use of the name Trinidad sandstone therefore seems preferable to the introduction of a new name, although it must be admitted that the sandstones may not be precisely synchronous deposits.

As recognized in this field the Trinidad sandstone ranges from 50 to 100 feet in thickness and includes only the massive sandstone beneath the Rockvale coal bed. For about 50 feet below it sandstone and shale are present in nearly equal amounts, and, as already mentioned, the upper 300 feet of the Pierre shale is very sandy. As the base of the Trinidad sandstone is not a sharp line, other observers might prefer to place it as much as 300 feet or more below the Rockvale coal, thus including sandstones and sandy shales which the writer has considered merely sandy members of the Pierre shale.

No fossils were found in the Trinidad sandstone, not even the peculiar lozenge-pattern prints of the marine plant often called fossil corncobs (*Halymenites major*), which is elsewhere so characteristic of this sandstone. The search for fossils in the Trinidad was not thorough, yet was sufficient to show that *Halymenites* is either absent or at least rare in the Trinidad at Canon City, although in a yellow sandstone in the coal measures about 300 feet above the Trinidad this fossil is very abundant. The sandstone is more massive and, in places, strongly cross-bedded on the west side of the coal field, suggesting that Wet Mountain was land and that the Canon City embayment was occupied by the sea at the time the Trinidad sandstone was deposited.

LARAMIE FORMATION.

The Laramie formation, which contains all the coal beds of the Canon City field, rests conformably on the Trinidad sandstone and is unconformably overlain by the Arapahoe (?) conglomerate. The productive division of the formation is the lower 600 to 700 feet, consisting of sandstone and dark-colored, usually carbonaceous shale. On the east side of the field the lower third of the productive division consists mainly of sandstone and the upper two-thirds mainly of shale, but on the west side sandstone predominates over shale in all parts of this division. Overlying the productive division is a resistant, massive sandstone about 250 feet thick, which is a controlling factor in the topography, producing a sharp ridge where it stands vertical along the western margin of the field and causing the high escarpment of nearly horizontal coal-bearing strata which it caps on the east side of the field. Above the resistant sandstone at Alkali Gap there is 255 feet of soft yellow sandstone in beds 2 to 5 feet thick separated by sandy shale and probably by some dark carbonaceous shale, but over the greater part of the field this, the highest member of the Laramie formation, is absent and the Arapahoe (?) conglomerate rests directly on the underlying thick massive sandstone. The character of the formation in the western part of the field is shown by the following detailed section of the rocks, which was measured by C. A. Fisher and the writer with a steel tape.

Section of rocks in Alkali Gap.

	Ft.	in.
Sandstone, tuffaceous, and bright colored clay, probably Denver formation, nearly horizontal	50	
Not exposed, horizontal distance 325 feet, dip unknown	?	
Sandstone, mostly, with layers of conglomerate, dip 75° E	160	
Not exposed, soft, probably dark shale	60	
Conglomerate	260	
Total exposed Arapahoe (?) [a]	480+	
Unconformity.		
Sandstone, soft, with streaks of sandy shale, nearly vertical	255	
Sandstone, strong, massive, makes crest of ridge	250	
Not exposed, probably mostly soft sandstone, some fire clay at top	40	
Coal, thin bed.		
Sandstone	25	
Not exposed, soft rocks	20	
Coal, probably Brookside bed	3	
Shale	2	
Sandstone, white, even bedded	20	
Sandstone, soft	35	
Not exposed	30	
Coal, in black shale	1	6
Not exposed	20	
Sandstone, with fossil leaves at base	55	
Coal, Chandler bed, in an open cut	4–5	
Sandstone and shale	40	
Coal, top not exposed	1+	
Sandstone, coarse grained, massive, with iron concretions, weathers yellow	65	
Sandstone, shaly	30	
Coal, upper Royal Gorge bed	4	
Shale, hard, sandy	10	
Coal, bloom, lower Royal Gorge bed [b]	4	
Sandstone, soft, white	27	
Shale, with coaly streaks	5	

[a] In the Littell shaft, 1 mile east of Alkali Gap, the thickness of the Arapahoe (?) is about 550 feet.

[b] Measurement obtained in the Royal Gorge mine. The lower bed can not be measured in Alkali Gap without considerable digging.

	Ft.	in.
Sandstone, soft, gray	31	
Coal { Coal, 2 feet; Shale, 1 foo; Coal, 1 foot }	4	
Not well exposed, probably mostly shale	41	
Sandstone, hard	8	
Not well exposed, mostly shale	52	
Coal	2	6
Sandstone and shale, with a nonworkable bed of coal near base	63	
Coal	?	
Sandstone	15	
Coal	?	
Shale	25	
Coal { Coal, 1 foot; Shale, 1 foot; Coal, 1 foot 8 inches } Nonac bed	3	8
Sandstone, coarse, white	50	
Coal, Rockvale bed		2–6
Total Laramie	1,242	
Sandstone, Trinidad	55	
Shale, blue, sandy	45	
Sandstone	1	
Shale	5	
Sandstone, massive	8	
Shale, blue, sandy, with thin partings of sandstone	40	
Shale, sandy, yellow, containing large concretions with Pierre fossils	45	
Shale, blue, sandy, with concretions	65	
Sandstone, soft, shaly	4	
Shale, sandy, blue, yellow, white	50	
Shale, blue, containing at base concretions with *Lucina occidentalis*	250	
Shale, blue-black, with thin indurated sandy layers containing comminuted plant fragments	150	
Shale, clayey, dark, slickensided [a]	3,000	
Total Pierre and Trinidad	3,718	
Fault.		
Granite.		

Coal is present only in the lower 600 feet of the Laramie formation, the overlying sandstones being barren in this field.

The rocks of the Laramie formation become much finer in grain toward the east side of the coal field. This change is especially noticeable in the upper part of the productive division, which consists principally of shale in the eastern part of the field and largely of sandstone in the western part, although there is considerable shale at the west also, as shown by the section in Alkali Gap given above. For

[a] The entire thickness of the Pierre shale is not present at this locality. In the Florence oil field it measures about 4,500 feet. See p. 519.

comparison with the Alkali Gap section, the following measurements of the strata exposed in the bluff north of Rockvale may be of interest.

Section of part of the Laramie formation on the hillside north of Rockvale.

	Ft.	In.
Sandstone, massive, probably part of the big barren sandstone	25	
Not exposed	15	
Coal, blossom	?	
Shale	25	
Sandstone	10	
Shale	25	
Coal, surface measurement	2	
Shale, dark, with three 1-foot beds of sandstone	25	
Coal, surface measurement		6
Shale, dark	35	
Sandstone, soft, and sandy shale	5	
Sandstone, strong, thin bedded, fine grained	6	
Coal, blossom, thickness probably	1	
Shale, mostly dark colored, with streaks of coal	45	
Sandstone, shaly	8	
Shale	4	
Sandstone	5	
Shale, carbonaceous	15	
Sandstone, soft, with layers of firm white shale	5	
Shale, dark, carbonaceous	12	
Sandstone, resistant	10	
Shale, dark	13	
Coal		2
Clay		2
Coal, surface measurement	1	
Bone	1	
Sandstone, soft, coarse grained, white, with brown ironstone concretions	8	
Shale	5	
Sandstone		6
Shale, black, carbonaceous, with many black clay-ironstone concretions	25	
Sandstone and shale, soft	4	
Coal, surface measurement	1	
Shale, sandy, weathering white	20	
Shale, black, carbonaceous	25	
Sandstone, massive	10	
Shale, carbonaceous	15	
Sandstone, strong, with gnarly brown concretions at top	12	
Shale, sandy	5	
Sandstones, massive	8	
Coal, surface measurement	2	2
Shale, carbonaceous and sandy	10	
Not exposed, rock beneath the valley	350±	
	794	6

The lower two-thirds of the concealed strata at the base of this section was measured near the Bluff Springs mine and a section of the rocks will be found on page 355. F. H. Knowlton reports that the upper part of the coal measures contains a flora equivalent to that of the Laramie formation of the Denver Basin, but that the lower part contains a flora of upper Montana age. According to the original definition of the Laramie by which the term includes the coal-bearing strata resting conformably on the top of the marine Cretaceous, there seems to be no good reason for separating these lower beds from the Laramie even though they contain an upper Montana flora. There is no noticeable lithologic change within the coal-bearing strata that can furnish a satisfactory basis of subdivision into a Laramie and an upper Montana formation, except on the eastern edge of the field north of Radiant, where a yellow thin-bedded sandstone 40 to 70 feet thick contains many impressions of *Halymenites major*, a marine plant. Knowlton reports that this sandstone separates the strata containing an upper Montana flora from the overlying beds, which contain a flora similar to the Laramie. When the sandstone is traced toward the mountains either southward beyond Radiant or westward to the west side of the field, it is seen to lose its marine character, its thin bedding, fossils, etc., and to become massive, coarse grained, and cross-bedded, acquiring all the characters of a fluviatile sandstone. On the west side of the field it is impossible to distinguish this sandstone from others above and below it, except by careful comparison of detailed sections, and it therefore has little value as a horizon marker in that region.

The lithologic succession in this field is almost precisely identical with that at Denver, and the writer therefore does not hesitate to correlate the strata of the Canon City coal field with those of the Denver Basin, admitting that on paleobotanic evidence the lower coal beds may be somewhat older than the lowest coal at Denver.

ARAPAHOE (?) CONGLOMERATE.

The Arapahoe (?) conglomerate rests unconformably on the sandstone at the top of the Laramie formation. In the Alkali Gap section (see p. 345), the conglomerate rests on a soft, distinctly bedded sandstone with layers of sandy shale, which measures 255 feet in thickness. This sandstone thins out northward, on account of pre-Arapahoe erosion, and half a mile north of Alkali Gap, opposite the Royal Gorge coal mine, the conglomerate lies directly on the lower resistant massive sandstone, which there measures about 235 feet in thickness. Apparently erosion had cut about 270 feet deeper in the rocks at the latter locality than it had at Alkali Gap before the deposition of the conglomerate. Over the whole of the Canon City field, except at

Alkali Gap, the conglomerate rests on the resistant massive sandstone, and the overlying soft sandstone is absent. At the gap the soft sandstone was presumably in some way protected from erosion.

As the Arapahoe (?) conglomerate lies unconformably on the Laramie it is not surprising that a few fragments of sandstone and coal of the Laramie are present in the conglomerate. Fragments of Pierre shale were not seen in the conglomerate, but the Niobrara and Paleozoic limestones and cherts and the Dakota (?) sandstone are represented by a few pebbles, and one fragment of Ordovician sandstone containing a fish scale was found. Small waterworn pieces of red sandstone from the "Red Beds" and rounded quartzite pebbles from an unknown source are abundant. Pebbles of all these rocks, however, are greatly outnumbered by those of Archean granite, granite gneiss, schist, quartz, and coarse-grained igneous rocks that intruded the Archean complex in pre-Ordovician time. The last-named rocks are common in Wet Mountain and all the sedimentary rocks which compose the minor part of the Arapahoe (?) conglomerate are found upturned along the front of the mountain, except that there is no quartzite like that of the pebbles. Diligent search failed to reveal any pebbles of effusive igneous lava or tuff such as characterize the Denver formation, but pebbles of coarse-grained porphyries are numerous, being probably derived from pre-Ordovician intrusions in the Archean complex. Granite pebbles and small pieces of granitic quartz and feldspar are by far the most abundant constituents of the conglomerate. Although the pebbles of sedimentary rock seem to be most plentiful in certain layers near the middle of the formation, there is essentially no difference in the materials of the conglomerate from bottom to top.

In Alkali Gap the lower 260 feet of the Arapahoe (?) is pure conglomerate with very little sand. It outcrops in massive beds about 20 feet thick. The basal bed contains the largest pebbles, which range from 3 to 10 inches in diameter and are mostly subangular but slightly waterworn. The rare quartzite pebbles, however, are all well rounded and smooth. Above the massive conglomerate are 60 feet of poorly exposed strata, probably soft sandstone or sandy shale, and some dark carbonaceous shale, seen only in the débris of rodent holes. In the succeeding 160 feet of strata there are four beds of pebbly sandstone, each about 10 feet thick, separated by intervals of 30 to 40 feet in which the rock is not exposed. To judge from the soil, the débris of prairie-dog holes, etc., these intervals in which the rock is not exposed are occupied by coarse sandstone, possibly with pebbly layers. The pebbles in the sandstone beds are mostly in layers 6 to 18 inches thick. They are similar in material to those in the underlying conglomerate, but are smaller, one-fourth inch to 1 inch in diameter, and more nearly rounded. Quartz pebbles are more abundant in the upper layers than in the massive conglomerate. These are the highest beds of the Arapahoe (?) conglomerate observed in the Canon City field. They dip 75° to 85° E. The succeeding interval, across 325 feet of ground, contains no exposures. The next exposure is that of beds of the Denver (?) formation lying horizontally. If the concealed rocks stand nearly vertical in this interval, they are about 325 feet thick, but it is probable that the dip is less steep and consequently that the thickness is much less than 325 feet, perhaps about 70 to 100 feet, for the total thickness of the Arapahoe (?) in the Littell shaft, about one-fourth mile east of this locality, is only 550 feet, the lower 480 feet of which has already been described as occurring at Alkali Gap, leaving only 70 feet to be accounted for. It is in this interval that the beds change abruptly from a nearly horizontal to a nearly vertical position.

The Arapahoe (?) conglomerate underlies the whole of Wolf Park, extending at least as far south as Chandler. Along the wagon road between Canon City and Chandler the conglomerate is well exposed on some high hills, where it dips northwestward at a low angle. In the southern part of the field it lies along the axis of the syncline, which is west of the center of the field. Its eastern margin can not be observed in the southern area, and its position as shown on the accompanying map (Pl. XVIII) is largely conjectural.

The Arapahoe (?) is very different from the underlying formations in the character and coarseness of its material. The presence of material from these formations in its pebbles indicates that a long period of erosion preceded the deposition of the conglomerate. The fact that it was involved in the last great orographic movements of the Rocky Mountains prevents the possibility of confusing it with late Tertiary gravel. The writer follows Eldridge, Hills, and others in correlating this formation with the Arapahoe of the Denver Basin.

DENVER (?) FORMATION.

At a distance of 325 feet east of the last exposure of Arapahoe (?) conglomerate in Alkali Gap the small creek that flows through the gap has undercut a few feet of green and red clays containing thin beds of brown and yellow sandstone with pebbly layers. The beds lie nearly flat, dipping not more than 3° or 4° E., but this does not indicate that they have not been involved in the folding of the lower formations. The structure makes it highly probable that the lower formations are also nearly horizontal at this locality. The exposure is imperfect. There is no indication of the existence of more than 50 feet of rocks assignable to this formation, yet from the presence of tuffaceous and andesitic material in the pebbles first reported by Eldridge, it seems best to follow him in considering the exposure a probable small remnant of the Denver formation. The rocks should be separated from the Arapahoe (?) conglomerate because of the presence of the distinctive andesite and red and green clays. There is no evidence of the existence of more than 1 acre of Denver (?) rocks, but more may be concealed beneath the valley wash on the west side of Wolf Park, outside of which it is not possible for any Denver (?) strata to be left in this region.

THE COAL.

STRATIGRAPHIC POSITION OF COAL BEDS.

As mentioned above, all the workable coal beds are in the Laramie formation. Indications of coal have been found in the Dakota sandstone, but as a rule the beds are thin and apparently of no value. (See p. 371.)

The correlation of coal beds which can not be accurately traced on the surface is not an easy matter; nevertheless the approximate position of any bed may be determined by geologic methods without serious error. In the following table the endeavor is made to project all the known coal beds on a section of the Laramie formation measured near Rockvale, for the purpose of showing the relative position of the beds. Some generalization has been necessary on account of differences in thickness of the beds away from the Rockvale section, and because not all of the coal beds are present in that section. The coal of many of the horizons can not be traced from one mine to another, and it is known that some of the coals are not continuous between mines that work beds at probably the same horizon.

Section of the Laramie formation in Canon City coal field, Colorado, showing the relative positions of the coal beds.

	Feet.
Unconformity at the base of the Arapahoe (?) conglomerate.	
Sandstone, resistant	250–500
Sandstone, soft, and shale, with thin coal beds	125
Horizon of the coal bed of the Brookside and Brilliant mines.	
Interval, mostly sandstone, with thin coals	75–165
Horizon of the coal bed of the Chandler and Littell mines and of the Simons prospect in Alkali Gap.	
Interval, mostly sandstone	95–135
Horizon of the Royal Gorge coal beds and possibly of the Bassick bed.	
Interval, mostly sandstone	70
Horizon of the Radiant coal bed.	
Interval, mostly shale	75–100
Horizon of the coal of the Ocean Wave or Magnet mine.	
Interval, sandstone and shale, with thin beds of coal	100–115
Horizon of the coal of the Nonac and Diamond mines.	
Sandstone	30– 50
Horizon of the coal of the Fremont, Rockvale, Coal Creek, and Bluff Springs mines. This coal bed is considered the base of the Laramie formation.	
Trinidad sandstone.	

DESCRIPTION OF MINES AND PROSPECTS.

Rockvale mine.—The Rockvale mine is the largest in the Canon City field, producing an average of 850 to 900 tons a day and at times over 1,000 tons a day. The mine is about thirty-five years old, having been first opened by the Santa Fe Railway Company from a shaft (Santa Fe No. 4), located one-half mile northeast of the present Rockvale shaft, which was completed by the Colorado Coal and Iron Company in 1881. The mine is operated by the latter company, reorganized under the name Colorado Fuel and Iron Company.

The Rockvale mine is in the lowest bed in the field and its workings merge and intercommunicate with those of the Fremont and Coal Creek mines, both of which are also operated and owned by the Colorado Fuel and Iron Company. The coal is hoisted by steam power through a two-compartment shaft 323 feet deep, the top of which coincides with the upper surface of the yellow sandstone, which here contains abundant impressions of *Halymenites.* The coal is dumped from a wooden tipple over screens directly into coal cars, most of the lump coal being loaded into box cars by a steel box-car loader operated by electricity. The fine coal is washed but does not find a ready market, and in 1908 a large amount of slack was piled beside the railroad track.

The coal bed rests on the Trinidad sandstone at the base of the Laramie formation. In the Rockvale mine it slopes westward from 6 to 6½ per cent and varies in thickness from 3 feet 4 inches to 4 feet, the thicker coal invariably being overlain by "draw slate" and the thinner coal usually by sandstone. This relation prevails throughout the three adjacent mines, Fremont, Rockvale, and Coal Creek, and is probably due to the erosion of the original clay and of the top of the original peat, which were consolidated to the "draw slate" and the coal, respectively. The erosion is supposed to have been effected by the swifter current that deposited the sand of the overlying sandstone. By platting the position of the places where the sandstone roof comes in contact with the coal in the three mines, significant relations have been discovered between the character of the coal beds, especially in regard to roof and partings, and the position of the stream channels in the swamps of the coal-forming period. The main stream channel as thus located lies just north of the Fremont workings, in the northern part of which the coal is of little value on account of partings. These relations will be fully discussed in the final report.

Mining is done wholly by hand in the Rockvale mine, the long-wall method being followed. The distribution of joints in the coal makes driving easiest in a northeast or southwest direction. In the first entry north of the C dip slope off the main south slope the butts trend N. 40° E. and the faces N. 50° W. The butts are 2 to 8 inches apart, with an average of about 5 inches; the faces are strongly developed and the distance between them varies from 1 to 4 inches, averaging about 3 inches. The joints appear to be of the same general character wherever examined in this mine. In the fourth entry south of the C dip slope off the main south slope the butts trend N. 45° E. and are spaced 2 to 12 inches, with an average of about 6 inches; the faces trend N. 50° W. and are spaced 1 to 3 inches, with an average of about 1½ inches.

The coal breaks down in lumps 1 to 3 feet across, with considerable quantities of finer débris. It is reported that in this mine, as well as in most of the other mines, the introduction of foreign workmen as a result of labor troubles in recent years has caused a marked falling off in the percentage of lump coal produced and in the general efficiency of the working force. As the Canon City coal is mined principally for domestic use, for which it commands a high price, the percentage of lump coal is an important factor in mine management.

In the Rockvale mine the coal cars are hauled by mules to the main slope, where they are attched to a cable and drawn by electric drums to the foot of the shaft. Gas is not abundant and the small amount present appears to come mainly from the coal and only in part from the roof.

Fremont mine.—The Fremont mine is on the same coal bed as the Rockvale mine and the workings of the two intercommunicate underground. The shaft of the Fremont is located about 1½ miles northwest of the Rockvale. The Fremont mine is operated by the Colorado Fuel and Iron Company and produces about 400 tons of coal a day in the following proportions: Lump coal, passing over 3-inch perforated shaker screen, 50–51 per cent; nut coal, 22–23 per cent; slack and pea coal, 21–22 per cent.

The shaft is 402 feet deep and is equipped with a hoist of 100 horsepower, steel top frame, and self-dumping cages handling about 75 cars an hour. The tipple is also built of steel and has a steam box-car loader and shaker screens. The trips of coal cars are hauled to the foot of the shaft by a 75-horsepower electric traction motor. Water is pumped by two small electric pumps from the working faces to a sump at the foot of the main shaft, whence it is raised to the surface by a 75-horsepower electric pump working two hours a day at a rate of 50 gallons a minute. In 1908 about 180 men were employed underground and 35 at the surface. The miners receive 85 cents a ton for hand mining.

The coal bed has an average thickness of about 4 feet, ranging from 3 feet to 3 feet 6 inches under the sandstone cap rock and from 4 feet 6 inches to 5 feet under shale. Sandstone comes into contact with the coal in the southeastern part of the mine, but in most other parts the cap rock is shale. The line of separation between the areas of sandstone and of shale cap rocks trends in a general northeast-southwest direction, running about 1,000 feet south of the shaft and continuing into the Rockvale mine. Southeast of this line the cap rock is sandstone in most places. Northwest of the line the cap rock is sandstone only where rolls or similar irregularities permit it to descend through the shale, which varies from 1 to 7 feet in thickness.

Joints are well developed in this mine. The butts trend N. 40° E. and are about three-fourths of an inch apart; the faces trend N. 50° W. and are half an inch to 2½ inches apart.

Coal Creek mine.—The Coal Creek mine of the Colorado Fuel and Iron Company is located in sec. 31, T. 19 S., R. 69 W., and ships its product over a spur of the Denver and Rio Grande Railroad running 3 miles northeastward to Florence. The mine is worked by a slope which now extends about a mile west of the entrance and has a dip of about 3°. It was first operated from a slope that lies three-fourths of a mile north of the present location and is commonly known as the old Coal Creek slope or the Canfield mine. The Coal Creek mine was not entered by the writer because of its proximity to the Rockvale and Bluff Springs mines, which work the same coal bed at the base of the Laramie formation.

The mine maps kindly furnished by the Colorado Fuel and Iron Company show that the thickness of the coal bed near the center of the SW. ¼ sec. 31, T. 19 S., R. 69 W., is 3 feet 3 inches, and one-fourth mile north of the southwest corner of sec. 31, T. 19 S., R. 69 W., 3 feet 6 inches.

Seven feet above the Rockvale bed at Coal Creek there is about a foot of coal which persistently accompanies the Rockvale bed in this part of the field. Its distance from the Rockvale bed increases toward the north to 10 feet in the Rockvale mine and to 15 feet in the Fremont mine. In the southwestern part of the Coal Creek mine the intervening rock, principally sandstone, which separates the top coal from the main bed, wedges out and permits the top coal to rest on the main bed with only a trace of separating clay.

The mining operations at Coal Creek are similar to those at Rockvale, the long-wall method being used exclusively. The production is somewhat smaller than that at Rockvale, owing largely to the fact that a slope is slower to operate than a shaft. Mining at Coal Creek is facilitated by the ease with which the coal breaks from the roof, owing to an intervening thin parting of argillaceous rock. In most parts of the Rockvale mine the cap rock is "frozen" to the coal, making clean extraction of the coal somewhat difficult.

Bluff Springs mine.—The Bluff Springs mine, locally known as the Blazing Rag, is a small mine now operated by J. T. McLean, of Florence, and located about 2 miles southwest of the town of Coal Creek. Its output, which is small, is hauled by wagon to Florence and neighboring towns. This is the most southerly mine working the Rockvale coal bed, which becomes thin farther south. The coal bed varies in thickness from 3 feet to 3 feet 6 inches in the Bluff Springs mine, including a clay parting 1 to 3 inches thick near the middle of the bed. The clay parting thickens southward to 18 inches at a distance of 2,000 feet from the shaft, the upper bench of coal becoming correspondingly thinner and more dirty until it disappears about half a mile south of the shaft. The lower bench continues with varying thickness at least as far as Radiant, where it is reported to be about 3 feet thick in an old prospect shaft near the tipple of the Radiant mine.

Section of the lower part of the Laramie formation at the Bluff Springs mine.

	Ft.	in.
Sandstone, yellow, with *Halymenites major;* the same bed that outcrops at the top of the Rockvale shaft and back of Williamsburg	40	
Not exposed	40	
Shale, dark, carbonaceous	10	
Coal [a]	2	2
Clay		4
Coal		6
Not exposed, probably mostly sandstone	10	
Sandstone, white, massive	10	
Sandstone, thin bedded	3	
Coal; varies in near-by prospects from 1 foot 8 inches to 2 feet 4 inches	2	
Rock not exposed, lying above the top of the air shaft	25	
Gravel, recent wash at the top of the air shaft	15	
Coal		7
Sandstone and shale	24	
Coal		8
Shale and thin-bedded sandstone	10	
Coal		6–8
Shale	5	
Sandstone	10	
Coal	1	6
Sandstone, hard, concretionary	3	
Shale, dark	12	
Coal	1	6
Shale		2
Coal	1	8
	226	7

The lower 80 feet of this section was measured in the new air shaft sunk in 1908. The rest of the section was measured on the surface.

Radiant mine.—The Radiant mine of the Victor Fuel Company is located in the western part of sec. 7, T. 20 S., R. 69 W. It is on a 3-foot coal bed whose position is estimated to be between 200 and 250 feet above the Rockvale bed, which is not workable near Radiant nor

[a] At another prospect 700 feet north-northwest of the Bluff Springs mine this coal is in one bench measuring 3 feet 10 inches in thickness.

farther south. In the Radiant mine the thickness of the coal bed varies from 3 feet to 3 feet 9 inches. A section of the coal in the northern part of the mine is shown below:

Section of coal bed in the Radiant mine.

	Ft.	in.
Shale.		
Coal	1	4
Shale		0–2
Coal	1	11
Shale.		
	3	4

Mining machines are used to undercut the coal, which breaks free from the roof when shot except in the tenth north entry, where it does not part readily from the roof, or in the miner's phraseology, is "frozen." The coal breaks down in long blocks 4 feet wide, 3 feet high, and sometimes 20 feet long when several holes are fired together. The blocks are usually 7 feet to 8 feet long for single shots.

Joints are strongly developed in the coal bed. The faces trend N. 47° W. and are from 1 to 1½ inches apart. The butts trend N. 50° E. and are 1½ to 3 inches apart. In the tenth north entry there is rude columnar jointing at the top of the coal bed. The columns are about 2 inches across and penetrate the coal for about 6 inches. They are very irregular in cross section. The origin of these joints is not known, but they are possibly due to weathering, although the coal is about 100 feet below the surface in this entry. No igneous intrusions have been noticed in this neighborhood.

Mining operations in the Radiant mine follow a combination of room-and-pillar and long-wall systems. The room-and-pillar method is used for a short distance on either side of the main slope, beyond which the coal is removed by the long-wall method. The coal is all undercut with electric machines, the mine being equipped with five Sullivan long-wall machines and one Jeffrey chain-breast machine. The machine men receive 7 cents a linear foot for undercutting. The loaders are paid 45 cents a ton. After the coal is loaded the mine cars are pushed to the main slope and there hooked to a cable that is drawn by an electric drum to the tipple, about one-fourth mile east of the mine mouth. The tipple is equipped with a steel automatic dump and shaker screens. It has one Westinghouse box-car loader. In the mine there is very little gas, and safety lamps have never been needed. Good ventilation is secured by a furnace at the foot of an air shaft in the southern part of the mine.

The coal appears to be softer and breaks much more easily than that in the northern part of the field. It also slacks more rapidly. Lump coal that had been piled in the open air at the Radiant mine for about three months in 1908 had begun to slack so badly that the miners reported that only about half of the original amount of lump coal could be obtained from the pile. The weathering of these lumps makes the cubical cleavage much more prominent than it is in the fresh coal. As many as six or eight strong joints to the inch appear. In the fresh coal the cubical cleavage can scarcely be distinguished.

The coal bed has an average westward dip of about 2° 15′. In the lower part of the mine the dip is in general about 2° and in the upper part about 3°, but there is much variation, produced apparently by broad open folds or "rolls" in the coal bed. These rolls cause alternate changes in dip of only about 1°, yet they are very noticeable on traveling up the slope. The dip at the end of the slope in 1908 was 2° W. In passing eastward from this point up the slope, dips of 1°, 3°, 2°, and 3° were successively encountered. As in all the rest of the eastern margin of the coal field, the coal bed dips most steeply at the mouth of the mine. This steepening of the dip near the outcrop is probably due to the weathering and expansion of the underlying beds, which are principally shale. It is very noticeable in the southern part of the field, where it is clearly not due to folding, because the line of steeper dips follows the front of the mesa, running up the gullies and around the points with the outcrop of the coal bed.

Shaw prospect.—A small amount of coal has been taken from a slope running eastward on the Radiant bed about one-fourth mile south of the Radiant mine. The entrance to this slope is on the east side of the creek that passes the entrance to the Radiant mine. Coal was hauled away by wagon previous to 1881, when the opening was closed. No further information about this prospect could be obtained at the time of the writer's visit.

Brilliant mine.—The Brilliant mine of the Diamond Coal Mining Company is located in sec. 25, T. 20 S., R. 70 W. It is operated by J. Walton and John D. Lloyd, of Canon City. The coal is hauled to Radiant by wagon and there loaded on railroad cars. The production is about 12 or 15 tons a day.

The coal bed, of which sections are given below, occurs in the upper part of the productive strata, probably at nearly the same horizon as the Brookside bed. It strikes N. 20° E. and dips 9° NW.

Sections of coal bed in the Brilliant mine.

Section 200 feet southwest of foot of shaft.

	Ft.	in.
Sandstone.		
Shale	1	2
Coal, dirty		2–10
Coal	4	6
Coal bed	5	

Section 100 feet southeast of foot of shaft.

	Ft.	in.
Sandstone.		
Shale		6
Bone		1½
Coal		5½
Bone		6
Shale		1
Coal	4	8
Coal, slightly bony		2
Coal bed	6	

The "draw slate" is removed in mining and the sandstone used as roof, which makes the rooms about 7 feet high. The top coal, 1 to 3 feet thick, is not quite clean but makes a satisfactory fuel for a steam boiler. In mining it is separated easily from the rest of the coal and is used in the operation of the mine. This top coal has a dull luster, doubtless due to its high ash content. (See analysis No. 6378, p. 374.) The rest of the coal bed, which varies in thickness from 4 feet 6 inches to 5 feet, is of a uniformly brilliant luster except for a number of dull layers, not over one-eighth of an inch thick.

The coal breaks readily along the bedding planes, a feature not observed elsewhere in this field. The faces trend N. 50° W. and are about 1 inch apart; the butts trend N. 30° E. and are 2 to 4 inches apart. Neither set appears to be very regular either in trend or in spacing.

The mine is operated by a small one-compartment shaft 96 feet deep, equipped with a steam hoist. A coal bed 2 feet 6 inches thick was penetrated by the shaft at a depth of 9 feet. The coal checks more rapidly in weathering than that of the mines in the northern part of the field. Although it does not keep quite so well as the latter, the coal of the Brilliant mine may be kept in stock several months without noticeable deterioration and is said to be a satisfactory domestic fuel.

Mountain mine.—The Mountain mine is a prospect shaft located near the middle of sec. 31, T. 20 S., R. 69 W. The mine is said to be completely caved in, having been idle for fifteen years, and therefore it was not visited. It is reported that about 9 feet of coal was present in this mine, the upper 2 feet being very dirty.

Chandler mine.—The Chandler mine of the Victor Fuel Company is located in the town of Chandler, near the southeast corner of sec. 22, T. 19 S., R. 70 W. It is on a coal bed, in the upper part of the Laramie formation, which lies from 75 to 100 feet below the Brookside bed and which is probably equivalent to the coal at the bottom of the Littell shaft in sec. 16. Typical sections in the eastern and south-central parts of the mine are shown below:

Sections of coal bed in Chandler mine.

Eastern part.

	Ft.	in.
Sandstone.		
Shale	0–3	
Coal	4	
Bone binder which does not break from coal		6
Coal	1	2
Coal bed	5	8

South-central part.

	Ft.	in.
Shale.		
Coal	3	6
Bone		1
Coal	1	4
Coal bed	4	11

The local thinning out of the shale overlying the coal appears to be due mainly to a slight erosional unconformity of the sandstone roof. In most parts of the mine there are "sand rolls" or long lines along which the sandstone cuts down through the "draw slate" and into the underlying coal. In places these sand rolls cut several feet into the coal and at one point a roll touches the bottom of the coal bed, the coal having been entirely removed at that point by erosion in the Laramie period. The sand rolls have round bottoms and curved sides, with no indication of sharp channeling. They trend northeastward in all parts of the mine. Some of them are several hundred yards long, but most of them are only a few hundred feet long. The width of the rolls varies from 10 to 30 feet. The shorter ones hang down in the workings of the mine very much like round-bottomed boats with broad ends. It seems probable that these sand rolls mark the position of stream channels that existed at a time immediately after the deposition of the "draw slate" over the coal. The cross-bedding in the rolls indicates that the streams flowed in a general northeastward direction.

In the northern part of the mine several small faults have been encountered. In the eighth entry west from the main north slope there is a small fault trending N. 10° E. This fault has a downthrow of 4 to 5 feet on the east side. In the seventh entry west off the main north slope there is a small fault which trends east and west and is downthrown 3 feet on the north side.

The room-and-pillar system is used in the Chandler mine, the rooms being driven with widths of 30 to 45 feet. The shale roof clings to the overlying sandstone and the coal breaks sharply from the shale when shot. Very large blocks are shot down in mining as described on page 84. Most of the coal is undercut with Sullivan electric chain cutters. The miners receive $1.05 a ton for hand mining. The two men on the cutting machines receive 5 cents and 4 cents a linear foot. The loaders from the machines are paid 40 cents a ton.

Great Western mine.—The shaft of the former Great Western Coal Company, commonly known as the Cuckoo mine, is located almost on the axis of the sharp flexure on the western margin of the field, in sec. 27, T. 19 S., R. 70 W. On account of this peculiar position with reference to the structure, the shaft penetrates horizontal rocks that are nearly vertical in the entries 300 to 470 feet west of it. In 1908 the mine was idle and in the hands of a receiver, but Mr. L. Lewis, who was temporarily in charge, kindly led the writer through the long crosscut that has been driven for 470 feet westward, across the strike of the upturned beds. The coal beds all appear to be considerably crushed by the upturning of the strata, and the condition of the tunnel was such that most of the rocks could not be satisfactorily measured without the expenditure of unwarranted time and risk of accident. The stratigraphic section of the steeply inclined rocks in this crosscut is approximately as follows:

Section of strata in the old crosscut of the Cuckoo mine.

	Ft.	in.
Sandstone	50	
Coal	1	5
Shale	2	
Coal	1	10
Shale	2	
Rock, mostly shale	50	
Coal	1	6
Shale	1	1
Coal	2	1
Rock, mostly sandstone	25	
Coal	2	3
Sandstone, with some shale	8	
Coal	1	1
Bone		5
Shale, dark	70	
Coal	1	11
Sandstone	10	
Shale	5	
Coal	1	2
Sandstone	5	
Shale	20	
Coal	3	2
Shale		4
Coal		5
Sandstone, with shale partings	30	
Coal, badly crushed in shale, measuring 2 to 4 feet, average probably	2	6
Shale	15	
	313	2

The shaft penetrates the upper part of the same rocks, but the coal beds are thicker in the shaft, according to the following section, taken from a blueprint kindly furnished by Mr. C. L. Mitten, the company's engineer:

Section of strata in the shaft of the Cuckoo mine.

	Ft.	in.
Sandstone	157	
Coal, average thickness	3	
Rock, mostly sandstone	140	
Coal	3	6
Rock, mostly shale	29	
Coal, average thickness	6	
	338	6

This mine has a steam hoist, electric fan, and modern tipple. It is connected by a short spur with the railroad track at Chandler. The mine has recently passed through a receivership and the new purchasers are said to be preparing to reopen it.

Diamond mine.—The Diamond mine is a small one-compartment inclined shaft 240 feet deep located on a nearly vertical coal bed one-fourth mile east of the southwest corner of sec. 17, T. 19 S., R. 70 W., about 4 miles south of Canon City. It is owned by A. C. Dickerson, of Canon City, and operated under lease by Lewis, McCloud, Kingston and Gunn. The average production in November and December, 1908, is said to have been 75 tons a month.

The coal bed varies in thickness from 3 feet to 3 feet 6 inches. The following section was measured near the bottom of the shaft:

Section of coal bed in Diamond mine.

	Ft.	in.
Shale.		
Coal	1	2
Shale		¼
Coal	2	2
Coal bed	3	4¼

The coal dips about 75° E. in the upper 100 feet of the shaft, and about 55° E. in the lower 140 feet. It is probably the same bed as the one at the Nonac or No. 5 mine, but the absence of surface exposures between the two mines makes reliable correlation impossible. The operators report that there is about 2 feet of coal in an old prospect shaft about 75 feet west of the mine. It is possible that the coal in this prospect is a lower bed. In a crosscut driven eastward, across the strike, from the Diamond mine 2 feet 6 inches of coal was encountered at a distance of 90 feet. If the 75° dip observed at the shaft prevails across this distance the stratigraphic position of the three beds is approximately as follows:

Section at Diamond mine.

	Ft.	in.
Coal, in crosscut, reported	2	6
Rock	72	
Coal, in Diamond mine	3	4
Rock	87	
Coal, in prospect shaft, reported	2	
	166	10

The coal in this mine is hard but locally crushed. It shows in places a marked development of joints, which make lozenge-shaped patterns when viewed in horizontal cross section of the nearly vertical bed. The acute angles of these lozenges, measuring 20° to 35°, lie in the direction of the strike and the supplementary obtuse angles lie in the direction of the dip. Some of the joints are slickensided. They are evidently the product of the same compressive shear that upturned the strata of the western margin of the field. The superposition of the lozenge joints on other sets of joints running more nearly parallel to the directions of strike and of dip makes the joints very intricate where both sets are developed. This is in marked contrast to the simple joints in the mines located in nearly horizontal strata already described.

Royal Gorge mines.—The Royal Gorge Coal and Fireclay Company operates two inclined shafts on an upturned coal bed about 3 miles south of Canon City. The mines have a combined annual production of about 65,000 tons, most of which is shipped by rail from No. 2 mine. No. 1 mine, one-fourth mile north of No. 2, ships its coal by wagon for local use only.

In the Royal Gorge mines there are two coal beds about 7 feet apart which are mined together. A typical section in mine No. 2 is shown below:

Section of coal beds in Royal Gorge mine No. 2.

	Ft.	in.
Sandstone.		
"Draw slate"	2	
Coal	4	
Sandstone, fine, and hard shale	7	
Coal	3	8

The upper bed is said to measure 5 feet 4 inches in mine No. 1, and the lower bed to measure 4 feet 6 inches in Alkali Gap, but these statements could not be verified owing to the inaccessibility of the old workings. A good coal bed 4 feet 6 inches thick, located about 165 feet stratigraphically above the Royal Gorge beds, was penetrated at a distance of 206 feet in a crosscut running 283 feet eastward across the strike from No. 2 mine. The following section was made in this crosscut:

Section of strata in crosscut east from Royal Gorge mine No. 2.

	Ft.	in.
Rock, mostly sandstone	55	
Coal, including a 4-inch clay parting	4	6
Sandstone	20	
Shale	15	
Coal	1	2
Shale, said to be fire clay	8	
Sandstone, white, massive	120	
"Draw slate," above the Royal Gorge coal	2	
	225	8

Another section of the same coal bed, measured 100 feet south of the crosscut, is as follows:

Section of coal bed in level from crosscut east from Royal Gorge mine No. 2.

	Ft.	in.
Sandstone.		
Shale	1	
Coal	2	6
Shale		3
Coal	1	2
Shale	2	5
Sandstone.		
Coal bed	3	11

About 200 feet west of the Royal Gorge bed Mr. Bettis has sunk a prospect shaft 95 feet deep in which a bed of coal 3 feet thick is said to have been struck at a depth of 75 feet. This is presumably the Nonac bed.

The method of working the two coal beds in the Royal Gorge mines is interesting, because the beds are separated by only 5 to 7 feet of rock of moderate strength, of which more than half is firm shale and the remainder is sandstone in beds 5 to 12 inches thick. The strata dip 50° E. In spite of these apparently unfavorable conditions the coal is remarkably free from dirt, as reported in analyses made for the power plant of the Arkansas Valley Electric Company at Canon City, and as shown by about 9 per cent of ash in the analysis of a car sample of the pea and slack coal (No. 6248).

The method of mining may be described as follows: From the main incline nearly horizontal levels are driven along the coals at about every 90 feet of depth. The coal is removed by upward stoping and drops through chutes into the mine cars on the levels. About 8 feet of coal is left temporarily as a roof to protect the levels. Black powder is used principally, with a small amount of giant powder in hard rock work. The lower coal bed is removed first and the thick parting of rock is allowed to settle into the stope, which it does slowly, breaking free from the bottom of the upper coal, which is then mined by the same method. No rock needs to be hauled to the surface except that removed in driving the levels. In 1908 the fifth level was being driven, at a depth of about 450 feet. The relative percentages of products obtained are: Lump coal, 40 per cent; nut coal, 25 per cent; pea and slack, 35 per cent.

Hayes mine.—The abandoned Hayes mine, located about one-fourth or one-half mile north of the Royal Gorge mines, probably worked the same coal bed. It was operated in the early days and the coal was hauled by wagon to Canon City. It is now completely caved in, and no information about it could be obtained.

Nonac mine.—The Nonac mine of the Colorado Fuel and Iron Company is located in Canon City, on the south side of Arkansas River. It is commonly known in the locality as No. 5, because it bore that number when operated by the Canon City Coal Company in the early days of this field. It is now No. 39 in the list of the Colorado Fuel and Iron Company. The mine is one of the oldest in the field, having been opened by Mr. Thornton in 1883.

The Nonac mine is worked from a slope running about half a mile to the southeast at an inclination of approximately 12°. The dip of the rocks at the mouth of the slope is 23° SE., but this high dip decreases within a short distance to 12°, which prevails throughout most of the mine.

The coal is the lowest workable bed in this locality, but it is about 70 feet above the Rockvale bed, which was cut through at the mouth of the slope but is worthless in this part of the field. The Nonac bed varies in thickness from 5 feet 8 inches to 6 feet 2 inches, except in the northern margin of the workings, where the coal is only 4 feet thick and contains a shale parting 10 to 12 inches thick near its middle. This parting wedges out toward the south and at a distance of one-fourth mile is represented by only a quarter of an inch of shale. Northeastward it thickens to 15 feet at the Prentiss shaft.

The mine employed about 90 men and produced about 300 tons a day before it was closed in December, 1907. The product was made up of lump coal, 55 per cent; nut coal, 20 per cent; pea and slack, 25 per cent. The mine is equipped with a steam 50-horsepower hoist, steam fan, wood tipple, stationary screens, and two electric mine pumps. At the time of the writer's visit in 1908 the mine was ventilated and kept in readiness to be reopened.

The coal from the Nonac mine is comparatively hard and stocks remarkably well. A large block of this coal several feet high has been standing exposed to the weather in front of a coal office in Canon City for sixteen years. (See p. 375.)

Prentiss shaft.—The Prentiss shaft was located near the center of sec. 4, T. 19 S., R. 70 W., about half a mile east of the Nonac mine. It has been abandoned for many years and no trace of it remains on the surface. John Arthur, of Canon City, reports that about 20 or 30 acres of coal was worked out from this shaft in 1888 and 1889, and that the coal bed was about 4 feet thick, becoming bony in the northern part of the mine. The mine had a good sandstone roof. The coal bed is 10 to 15 feet above the Nonac bed and is thought to be the upper bench of that bed, separated by the increased thickness of the parting which was noticed near the middle of the bed in the Nonac mine.

Littell mine.—The Littell mine, in Wolf Park, 3 miles southeast of Canon City, is operated by the Colorado Central Coal and Mining Company, under the control of the Littell Brothers Coal Mining Company, of Colorado Springs. The shaft is located in the deepest part of the coal basin and has a depth of 1,065 feet, which is not exceeded by any other coal shaft in the State. The mine is on a bed of good clean coal 5 feet 6 inches to 5 feet 10 inches thick, probably the same bed which is mined at Chandler and which is exposed in an open cut in Alkali Gap, where considerable impurity is present. (See section, p. 358.) In 1908 mining operations were curtailed, awaiting the completion of a spur from the railroad. The following section of the rocks was kindly furnished by the miners who sank the shaft:

Section of rocks in the shaft of the Littell mine, Wolf Park.

	Ft.	in.
Sandstone, with blue pebbles	80	
Conglomerate	10	
Sandstone and conglomerate	110	
Conglomerate, mostly	100	
Sandstone and conglomerate in layers	250	
(Total Arapahoe (?) conglomerate, 550 feet.)		
Sandstone	100	
Clay	40	
Sandstone, solid	100	
Sandstone, with clay partings	80	
Coal		3
Sandstone, mostly	45	
Coal	1	6
Sandstone (?)	12±	
Shale	25	
Sandstone	2	6
Shale	3	6
Coal, probably Brookside bed	2	
Bone		3
Sandstone	22	
Shale	2	
Coal		10
Shale	5	
Sandstone	45	
Sandstone, very hard, "quartzitic"	2	
Sandstone and shale	7	
Sandstone	6	
Shale	9	
Coal, probably Chandler bed	5	8
	1,065	6

The strike of the rocks at the bottom of this shaft is north and south; the dip 5° W. The shaft is equipped with a 75-horsepower steam hoist and an electric pump with a capacity of 100 gallons a minute. About 2,000 gallons of water an hour was entering the shaft in July, 1908, mainly from the upper sandstones and conglomerates. A little water also enters from the joints in the roof of the coal bed, but not in sufficient quantity to cause trouble. It is probable that when the water that enters the shaft from the upper sandstones is cased off there will be little trouble from this source.

At the time of the writer's first visit to this mine, in July, 1908, the shaft had reached a coal bed at a depth of 950 feet and prospect drifts had been extended on the bed for several hundred feet because it was thought to be the Rockvale bed, which is the lowest coal of this field. But on comparison of the foregoing section with the section measured in Alkali Gap (pp. 345–346), it became apparent that the prospect entries were being driven on a bed (the Brookside ?) that lies over 400 feet above the Rockvale bed and about 75 or 80 feet above the Chandler bed, which has an excellent development 2 miles north and 1 mile west of the mine. The Chandler bed was then sought by drilling and was encountered at a depth of 98 feet below the Brookside (?) bed. Those who now believe that the bed being worked at present in the Littell shaft is the Rockvale bed would do well to compare the section in the shaft with that in Alkali Gap. It will appear from this comparison that the Rockvale bed in the center of sec. 16 has a depth of about 1,450 feet, unless the rocks change considerably in thickness east of the gap. The Rockvale bed probably reaches a maximum depth of about 1,500 feet in the southwestern part of Wolf Park, which, therefore, must be either a deep syncline or a downfaulted block. A few east-west step faults, downthrown on the north side, have been encountered in the northern part of the Chandler mine. If more of these faults, or one large fault of the same kind, intervene between the Chandler workings and the Littell shaft, they may explain the discrepancy in depth of the Chandler bed in the two mines. In the imperfect exposures of Arapahoe (?) conglomerate that cover the intervening country no faults could be found. The dips fail by about 150 feet to explain the difference in depth. Dips determined in the conglomerate, which was laid down on stream beds that may have had an initial slope of 5° or more, are not satisfactory, and the true correlation of these beds must be ultimately determined by mining operations. Thus, on the east side of Wolf Park the bedding planes in the conglomerate dip 12° W. This conglomerate was laid down as coarse gravel by streams flowing eastward from the mountains. If the gravel beds had an initial slope of 5° E., like many of the deposits in the existing creeks, the conglomerate must have been tilted westward through an angle of 12° plus 5°, or 17°. The coal beds would dip 17° W. under these conditions, thereby explaining most of the discrepancy in depth between the coals in the Littell mine and those east of Wolf Park. Failure to appreciate this structure and the fact that the overlying barren measures are nearly 1,000 feet thick in Wolf Park has caused the abandonment of prospect drilling in this locality several hundred feet short of the most valuable coal bed.

No sample for analysis was collected from the main bed at the Littell mine, but a sample was obtained of the upper (Brookside ?) bed and the analysis (No. 6257) is given on page 373.

Brookside mine.—The Brookside mine of the Colorado Fuel and Iron Company is located in sec. 11, T. 19 S., R. 70 W. It is one of the oldest and was once the largest producer in the Canon City coal field. Its product was well known and in high demand in Colorado. The mine was opened over twenty years ago and produced about 1,000 tons a day for several years, but the output was later allowed to fall to 250 tons a day, when the company developed other mines in which the cost of production was less. Since January 28, 1908, the mine has been shut down, and at the time of the writer's visit in the succeeding summer the workings were rapidly filling with water. For this reason and for lack of ventilation it was impossible to enter the mine, hence all of the information obtainable was that derived from mine maps and from the miners left in charge of the property.

The coal is the highest workable bed of the Canon City field. The operators report that throughout most of the mine the bed averages 5 feet 6 inches to 6 feet in thickness, but becomes thin and dirty at the south end of the mine, about a mile from the entrance. At the southwest end of the mine there is 3 feet of coal, and at the west end, east end, and center the sections are as follows:

Sections of coal bed in Brookside mine.

West end of mine.	Ft.	in.
Coal		9½
Bone		2½
Coal	4	1
Coal bed	5	1

East end of mine.	Ft.	in.
Coal		2
Bone	1	
Coal	3	
Coal bed	4	2

Central part of mine.	Ft.	in.
Sandstone.		
Shale	½-2	
Coal		6
Bone		2
Coal	6	
Coal bed	6	8

In mining the lower coal breaks from the bone, which is left as roof. The coal dips south-southwest, the angle of dip gradually decreasing down the slope. For the first 1,000 feet in from the entrance the dip is about 8 per cent, and for the next 4,000 feet it is about 6 per cent. The abandonment of the mine is thought to be permanent, as nearly all the coal that can be extracted profitably from this slope is said to have been removed.

Brewster mine.—The Brewster mine covered about 80 acres of coal of the Rockvale bed in the NW. ¼ sec. 18, T. 19 S., R. 69 W. It has been idle for about ten years and the workings are completely caved in. No measurement of the coal bed could be obtained, but it is reported that the thickness varied from 3 feet 6 inches to 4 feet in the eastern part of the mine and was about 2 feet 6 inches in the northwestern part.

Magnet mine.—The Magnet mine of the Rocky Mountain Fuel Company, often called the Ocean Wave mine, is located near the center of sec. 19, T. 19 S., R. 69 W. In 1908 it was shipping about 200 tons a day. It is on a 3 to 4 foot coal bed, which is the first coal above the Rockvale bed on the east side of the field, the Nonac bed being absent except in the northwestern part of the field. At the end of the main slope in 1908 the coal was 4 feet thick, including two or three clay partings about one-eighth inch thick. In the sixth east room off the third south entry the following section was obtained:

Section of coal bed in Magnet mine.

	Ft.	in.
Sandstone.		
Shale	1	9
Coal	3	5
Shale.		

In the main south entry 400 feet from the main slope the coal bed measured 4 feet 3½ inches, as shown below. The middle parting thickens northwestward in the mine, as shown by the section measured on the face of the third south entry from the main slope.

Sections of coal bed in Magnet mine.

Main south entry.	Ft.	in.	Third south entry.	Ft.	in.
Coal	2	2	Coal	2	3
Shale		3½	Shale		4
Coal	1	10	Coal	1	11
Coal bed	4	3½	Coal bed	4	6

The parting is said to increase in thickness and in coarseness of grain to the northwest, becoming 2½ feet of sandstone at the northwest end of the mine. Three sets of joints were observed in the coal in this mine. The two strongest sets trend N. 60° W. and N. 30° to 45° E. The former are 2 to 3 inches apart and the latter about 1 inch apart. A minor set of weak joints trending N. 30° W. was observed at a few places. The miners believe that the coal picks easiest on the east-west faces.

About half the coal is machine mined. Three Sullivan electric chain-breast machines are used. For hand mining in 1908 the miners received 90 cents a ton. Considerable giant powder is necessary in many parts of the mine owing to the hardness of the coal, to the tightness with which it clings to the roof and floor, and to the local abundance of hard "niggerheads." This is probably one of the causes for the low percentage of lump coal obtained. The relative proportions of the product are: Lump, 51 per cent; nut, 19 per cent; slack and pea, 30 per cent.

The mine is worked from a slope running westward down the dip of the bed. As in all the slopes starting from the eastern outcrop of the coal, the inclination is greater near the surface than it is farther down the slope. In the Magnet mine the dip is about 13° W. for the first 300 feet and then changes rapidly to 5° W. and finally to 4° W. in the last 900 feet of the slope.

The room-and-pillar system had been followed up to the summer of 1908, when the long-wall system was adopted, because its use in the other mines of the field has fully demonstrated that it results in a saving of 15 to 40 per cent on mine timber and in a considerable increase in the percentage of lump coal obtained, owing to the absence of crushing of pillars and to the greater ease of working a long uninterrupted face. In this mine there is locally also considerable "draw slate" and other débris which is most easily disposed of by piling it immediately behind the miners as they advance the long-wall face. Owing to the bad shale roof, heavy timbering was formerly required in the mine.

This mine has little gas and most of that encountered is believed to come from the roof and the top coal. The fire boss reports having observed one small harmless blow of fire damp which came from the top of the coal and which was exhausted in a few hours. As in all the mines of this field, gas has never caused any trouble and safety lamps are rarely required and then only in places of local escape of gas.

The coal bed of the Magnet mine is not exposed at the surface but covered by soil. It is known to extend at least 1½ miles south of the entrance to the mine. North of the mine the bed continues for about the same distance with varying thickness. In the wagon road southwest of the schoolhouse in sec. 12, T. 19 S., R. 70 W., the bed is reported by Simon Smith to be 5 feet thick. Near Mr. Smith's house, in the SW. ¼ SW. ¼ sec. 7, T. 19 S., R. 69 W., the coal is absent and the roof sandstone rests on the stratum beneath the coal. The same condition is reported in an old prospect about one-fourth mile northwest of the Emerald mine. It is probable that the absence of the coal is due to a "sand roll" or local unconformity marking the position of a stream channel of the Laramie epoch.

Walsh mine.—The Walsh mine is a small mine from which coal was hauled by wagon. It is located about one-fourth mile north of the Magnet mine and on the same coal bed. The coal has about the same thickness as in the Magnet mine, but the parting in the bed is sandstone from 12 to 18 inches thick. The opening is said to be utilized at present mainly in drawing old pillars in the northern part of the Magnet mine.

Emerald mine.—The Emerald mine, owned and operated by Simon Smith, is a small mine about a mile north of the Walsh mine and 3 miles west of Florence, in sec. 18, T. 19 S., R. 69 W. The coal, which is probably the Rockvale bed, varies from 3 feet 3 inches to 3 feet 10 inches in thickness, including in places two clay partings each about one-eighth of an inch thick.

The mine is worked from a slope which in 1908 was 550 feet long. The slope is inclined 4° 45′ for the first 300 feet from the entrance and 3° 40′ for the next 250 feet. A similar increase in dip near the surface of the ground has been noted in nearly all the slopes on gently dipping rocks in this field. It is thought to be due in most places to the weathering and expansion of the underlying rocks. The coal is hauled from this mine by wagon.

Willey mine.—The Willey mine is located in the SE. ¼ sec. 18, T. 19 S., R. 69 W. Entries Nos. 1 and 2, which opened on Oak Creek, are now abandoned. Entry No. 4, about one-fourth mile south of No. 2, is in a small gully that trenches the east side of the lower escarpment. None of these mines was large, and all of the coal was hauled from them by wagon, principally for local consumption. No. 3 is now operated by the Florence Fuel Company. It works the Rockvale bed, which has the following thickness:

Section of Rockvale coal bed in Willey mine No. 3.

	Ft.	in.
Sandstone.		
"Draw slate"		2–18
Coal	3	6
Sandstone.		

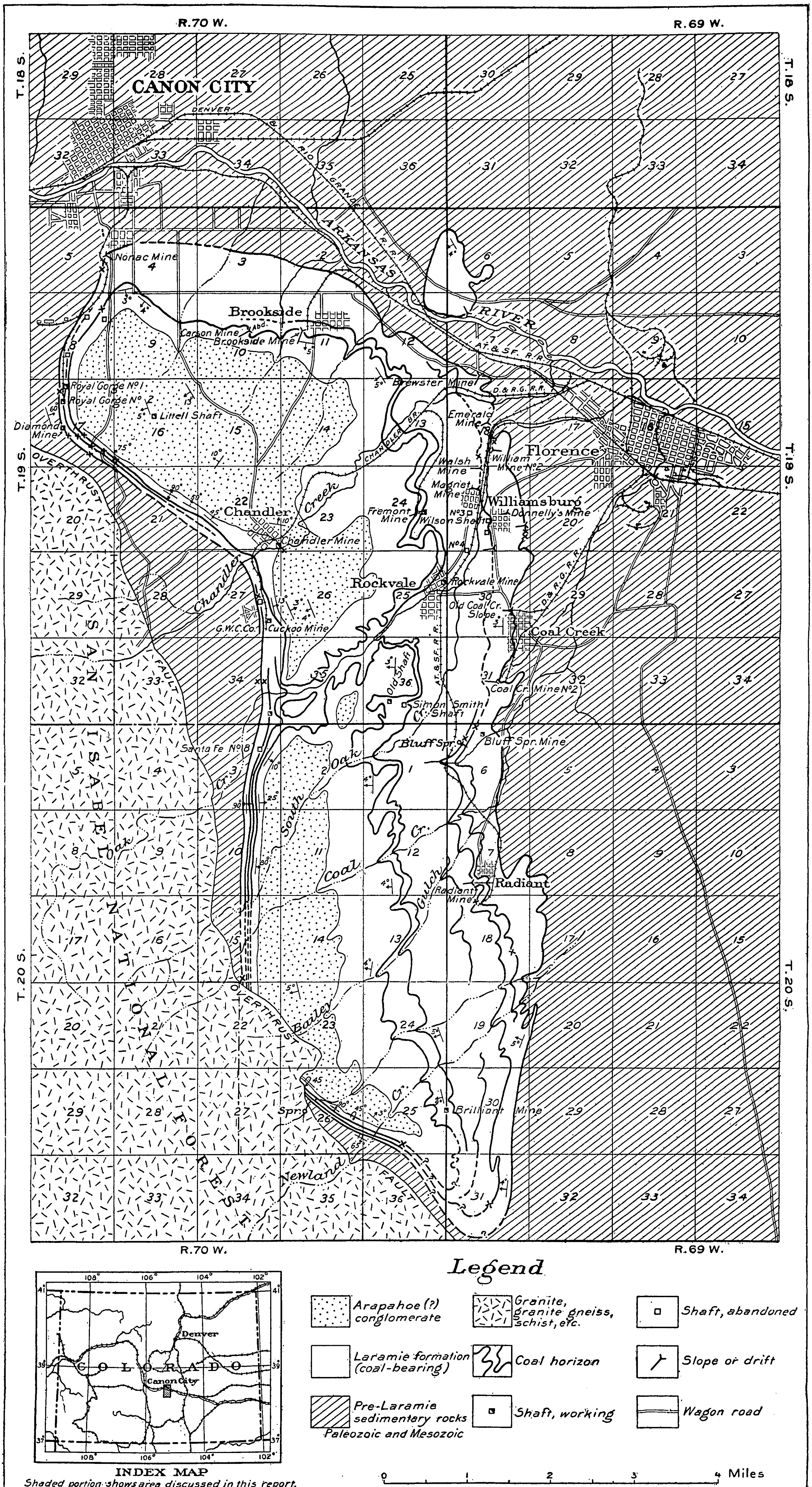
Santa Fe No. 8 mine.—No. 8 mine of the Atchison, Topeka and Santa Fe Railway Company is located on the steeply dipping western margin of the coal field, about 3 miles west of Rockvale. The mine was a steep incline, with a slope of about 30° E., about 1,000 feet deep, that worked a coal bed at approximately the same horizon as the beds in the Chandler and Littell mines. It has been abandoned for many years and can not be entered. The coal is said to be 4 feet 6 inches to 5 feet thick.

Bassick mine.—The Bassick mine is a steep incline located on the upturned coal strata in the southeast corner of sec. 27, T. 19 S., R. 70 W. It is an old mine, having been opened over thirty years ago. The production was small and all the coal was hauled by wagon, most of it to the Bassick gold mine, on the west side of Wet Mountain. The mine has been idle for many years except during the miners' strike four or five years ago, when a few tons were taken out. The coal bed, which is said to average about 5 feet in thickness and to vary greatly in character, occurs at about the same horizon as the Royal Gorge beds or possibly about 50 feet lower. In 1908 the mine was filled with water and could not be entered beyond a distance of about 50 feet down the slope. At the latter point the following section was measured:

Section of coal bed in the entrance to the Bassick mine.

	Ft.	in.
Shale.		
Coal	1	
Shale		2
Coal	4	
Coal bed	5	2

About 150 yards northwest of the Bassick mine the following section was measured on the east side of Oak Creek.



San Isabel National Forest boundary, June 12, 1905

MAP OF CANON CITY COAL FIELD, COLORADO.

By C. W. Washburne.

Section northwest of Bassick mine.

	Ft.	in.
Sandstone, resistant	20	
Shale, sandy in the upper part	10	
Coal, probably Nonac bed, surface measurement	2	1
Shale, carbonaceous, with sandy layers	20	
Sandstone, soft, argillaceous, weathering white	20	
Coal		4
Shale, carbonaceous, probably Rockvale coal horizon	2	
Sandstone, soft, white, argillaceous, weathering into a sandy clay	35	
Sandstone, hard, yellow, thin-bedded, Trinidad sandstone	40	
Sandstone and shale in beds 1 to 4 feet thick with ripple marks and fossil leaves	25	
Shale, Pierre.		
	174	5

Simon Smith shaft.—The Simon Smith prospect shaft was sunk for the purpose of reaching the Rockvale coal bed in the southern part of sec. 36, T. 19 S., R. 70 W. It is said to be 218 feet deep, mainly in sandstone, and to cut one workable coal bed. Work had stopped at the shaft in 1908, because the depth to the Rockvale coal bed was calculated to be 570 feet. Inspection of the strata at this locality makes it seem probable that the depth to the Rockvale coal is less than this, possibly not over 500 feet.

Coal prospect in the Dakota sandstone.—Verne Baumgartel has sunk a small prospect shaft on a coal blossom in the Dakota sandstone on his farm 3½ miles south of Canon City. The bed is from 6 inches to 2 feet thick and stands nearly vertical, between beds of massive sandstone, from which it is separated in places by shale partings that are reported to be fire clay. The coaly substance is hard, black, and crushed by shearing movements along the bedding planes into lenticular, slickensided fragments 1 to 3 inches long. Although these shiny fragments closely resemble hard coal, it is evident from the high ash shown by the following analysis that the material is bituminous shale and probably of no value.

Proximate analysis of air-dried coal from Baumgartel prospect, 3½ miles south of Canon City.

[Laboratory No. 6256.]

Moisture	8.10
Volatile matter	24.55
Fixed carbon	20.91
Ash	46.44
Sulphur	.48
Air-drying loss	8.00

No other indications of coal have been observed in the Dakota sandstone in the Canon City region, although the formation is well exposed and it has been pretty thoroughly prospected for fire clay. A tunnel has been driven through the Dakota hogback at Canon City without encountering coal. Evidently there is no warrant for further efforts to find coal in the Dakota sandstone in this vicinity.

CHARACTER OF THE COAL.

The coal of the Canon City field is well known in the West as a high-grade domestic fuel. Practical tests have shown that it does not coke. When ground in an agate mortar, the powder falls clean from the sides of the mortar and does not adhere to the end of the pestle. This test has been found by M. A. Pishel,[a] of the United States Geological Survey, to indicate the noncoking character of a coal.

The absence of the coking property makes the coal cleaner to handle and therefore more desirable as a domestic fuel, although it would be better for steaming purposes if it had a tendency to coke. The coal is firm and hard and produces comparatively little dust in handling. It has a well-developed system of cubical joints, which are one-eighth to one-fourth inch apart, but the fresh coal does not break along these planes unless struck a hard blow. The coal burns with a short bluish flame under draft and with a slow whiter flame in a stove. Grates of the type commonly used under steam boilers are evidently poorly adapted to this coal, as an unusually dense and abundant smoke issues from the funnels when it is burned under boilers, as may be seen at the works of the United Oil Company in Florence and to a less extent at the Arkansas Valley Electric Company's power plant in Canon City. At the latter plant it is found desirable to mix the slack of noncoking Canon City coal with slack of coking coal from the Trinidad field. By careful regulation of the hand stoking and of the draft the smoke can be considerably reduced, but it is reported that a satisfactory grate has not been found for Canon City slack coal.

The chemical properties and calorific power of some of the Canon City coals will be found by inspection of the following table. Samples were collected from all the mines and sealed in galvanized-iron cans with adhesive tape, but in the writer's ignorance of the rapid deterioriation of coal under such conditions[b] he kept many of these samples for several months after collecting. It is doubtful whether under such conditions an analysis of them would give accurate results or not. It will, therefore, be found that several of the principal mines are not included in the following table. The samples were all collected by cutting a uniform trench across the coal bed, then comminuting the material, mixing, quartering, and rejecting opposite quarters, the last process being repeated until the residue would fill a 3-pound sample can. Partings over half an inch thick were rejected. The cans were sealed within the mines immediately after the samples were collected.

[a] Econ. Geology, vol. 3, 1908, p. 266.
[b] See Parr, S. W., and Hamilton, N. D., The weathering of coals: Econ. Geology, vol. 2, 1907, p. 693.

Analyses of coal samples from the Canon City coal field, Colorado.

[F. M. Stanton, chemist in charge.]

Laboratory No.	Location.			Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Sec.	T. S.	R. W.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
				Ft. in.	*Ft. in.*													
6249	17	19	70	4 6	4 6	8.1	As received	15.0	34.2	45.7	5.08	0.54	5.52	60.76	0.91	27.19	6,024	10,843
							Air dried	7.5	37.3	49.7	5.53	.59	5.03	66.11	.99	21.75	6,556	11,801
							Dry coal	....	40.2	53.8	5.98	.64	4.53	71.47	1.07	16.31	7,086	12,755
							Pure coal[a]	....	42.8	57.2	....	.68	4.82	76.01	1.14	17.35	7,537	13,567
6252	17	19	70	4	4	6.1	As received	12.4	36.7	44.5	6.41	3.03	5.38	61.12	.90	23.16	6,160	11,088
							Air dried	6.7	39.1	47.4	6.83	3.23	5.01	65.09	.96	18.88	6,560	11,808
							Dry coal	....	41.9	50.8	7.31	3.46	4.57	69.71	1.03	13.92	7,026	12,647
							Pure coal	....	45.2	54.8	....	3.73	4.93	75.21	1.11	15.02	7,580	13,644
6253	17	19	70	3 8	3 8	4.5	As received	11.2	36.8	45.7	6.29	.92	5.44	62.50	.96	23.89	6,270	11,286
							Air dried	7.0	38.5	47.9	6.59	.96	5.17	65.45	1.01	20.82	6,565	11,817
							Dry coal	....	41.4	51.5	7.08	1.04	4.73	70.38	1.08	15.69	7,060	12,708
							Pure coal	....	44.6	55.4	....	1.12	5.09	75.74	1.16	16.89	7,598	13,676
6254	22	19	70	4 11	4 1	3.3	As received	9.9	35.3	48.6	6.21	.43	5.10	64.02	.91	23.33	6,357	11,443
							Air dried	6.8	36.5	50.3	6.42	.44	4.89	66.20	.94	21.11	6,574	11,833
							Dry coal	....	39.1	54.0	6.89	.48	4.44	71.04	1.01	16.14	7,050	12,697
							Pure coal	....	42.1	57.9	....	.52	4.77	76.30	1.08	17.33	7,576	13,637
6257	16	19	70	2	2 1	6.2	As received	13.0	33.2	46.4	7.38	.63	5.50	61.46	.90	24.13	6,045	10,881
							Air dried	7.2	35.4	49.5	7.87	.67	5.13	65.52	.96	19.85	6,445	11,601
							Dry coal	....	38.1	53.4	8.48	.72	4.67	70.63	1.03	14.47	6,947	12,505
							Pure coal	....	41.7	58.3	....	.79	5.10	77.18	1.13	15.80	7,591	13,664
6250	17	19	70	4 4½	4 4½	17.2	As received	23.2	30.3	40.2	6.28	.95	6.15	54.62	.79	31.21	5,348	9,626
							Air dried	7.2	36.6	48.6	7.59	1.15	5.12	65.97	.96	19.21	6,459	11,626
							Dry coal	....	39.5	52.3	8.17	1.24	4.65	71.10	1.03	13.81	6,961	12,530
							Pure coal	....	43.0	57.0	....	1.35	5.06	77.43	1.12	15.04	7,581	13,646
6251	5	19	70	6	6	4.8	As received	11.1	33.6	49.9	5.39	.93	5.18	63.67	1.04	23.79	6,347	11,425
							Air dried	6.6	35.3	52.4	5.66	.98	4.88	66.88	1.09	20.51	6,667	12,001
							Dry coal	....	37.8	56.1	6.06	1.05	4.44	71.60	1.17	15.68	7,138	12,848
							Pure coal	....	40.3	59.7	....	1.12	4.73	76.22	1.25	16.68	7,598	13,676

[a] "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated but owing to the briefness and convenience of the term it is used in this report as noted above.

Analyses of coal samples from the Canon City coal field, Colorado—Continued.

Laboratory No.	Location.			Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Sec.	T. S.	R. W.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
				Ft. in.	*Ft. in.*													
6376	25	19	70	3 8	4	0.6	As received	5.5	38.0	44.4	12.10	0.72	5.52	64.05	1.09	16.52	6,600	11,880
							Air dried	4.9	38.2	44.7	12.18	.72	5.48	64.44	1.10	16.08	6,640	11,952
							Dry coal		40.2	47.0	12.80	.76	5.20	67.73	1.15	12.36	6,980	12,564
							Pure coal		46.1	53.9		.87	5.96	77.67	1.32	14.18	8,005	14,409
6377	25	20	70	5 4	(*a*)	3.0	As received	13.0	31.5	53.2	2.26	.73	5.39	65.09	.80	25.73	6,303	11,345
							Air dried	10.3	32.5	54.9	2.33	.75	5.22	67.10	.82	23.78	6,498	11,696
							Dry coal		36.3	61.1	2.60	.84	4.54	74.80	.92	16.30	7,243	13,037
							Pure coal		37.2	62.8		.86	4.66	76.80	.94	16.74	7,436	13,385
6378	25	20	70	5 4	*b* 10	1.9	As received	9.1	31.7	36.6	22.61	.48	5.09	51.33	.93	19.56	5,163	9,293
							Air dried	7.3	32.3	37.3	23.05	.49	4.97	52.32	.95	18.22	5,263	9,473
							Dry coal		34.9	40.2	24.86	.53	4.49	56.44	1.02	12.66	5,677	10,219
							Pure coal		46.4	53.6		.71	5.98	75.11	1.36	16.84	7,556	13,601
6379	25	20	70	5 4	4 6	2.9	As received	11.2	34.8	44.1	9.88	.51	5.28	59.94	1.02	23.37	5,961	10,730
							Air dried	8.5	35.9	45.4	10.18	.53	5.11	61.73	1.05	21.40	6,139	11,050
							Dry coal		39.2	49.7	11.12	.57	4.55	67.46	1.15	15.15	6,709	12,076
							Pure coal		44.1	55.9		.64	5.12	75.90	1.29	17.05	7,548	13,586
6409	6	20	69	3 4	3	6.5	As received	10.3	32.7	42.7	14.29	.54	5.26	58.09	1.05	20.77	5,813	10,463
							Air dried	4.0	35.0	45.7	15.28	.58	4.86	62.13	1.12	16.03	6,217	11,191
							Dry coal		36.5	47.6	15.92	.60	4.59	64.72	1.17	13.00	6,476	11,657
							Pure coal		43.4	56.6		.71	5.46	76.97	1.39	15.47	7,702	13,864

a Bright layers. *b* Dull top coal.

6249. Royal Gorge mine No. 2, 3 miles south of Canon City. Sample from upper bed in crosscut from level No. 5.

6252. Same. Sample from middle bed on level No. 6. Sample wet.

6253. Same. Sample from lower bed on level No. 6, south side of main entry. Sample wet.

6254. Chandler mine, 6 miles southeast of Canon City. Sample from room No. 1, Cuckoo entry. Sample dry.

6257. Littell mine, 3½ miles south-southeast of Canon City. Sample from upper bed in first entry south, 100 feet from foot of shaft. Sample wet.

6250. Diamond mine, 3½ miles south of Canon City. Sample from level No. 2.

6251. Nonac mine, locally known as No. 5, 2 miles south of Canon City. Sample from working face 2,600 feet east of mouth of mine. Sample wet.

6376. Rockvale mine, Rockvale. Sample of 4 inches of hard greasy coal resembling cannel at top of bed in fourth dip in fourth north entry.

6377. Brilliant mine. Sample of bright, shiny layers, particularly abundant in top, bony coal.

6378. Same. Sample of dull top coal.

6379. Same. Sample of main part of coal bed.

6409. Bluff Springs mine, locally known as Blazing Rag, 2 miles south of Rockvale.

The coal of the Canon City field stocks unusually well. It may be kept for several years without much slacking, but of course, as in all coals, some deterioration sets in as soon as the coal is exposed. This is said to be less noticeable in the Canon City coal than in most western coals. The coal is not liable to spontaneous combustion, as attested by the large unburned slack piles at several places. In the mine dumps it catches fire and burns slowly for years. Parts of old dumps which have been abandoned for several years are still warm from the slow combustion of the coal.

A good example of the keeping quality of the Canon City coal is a large block of the coal which stands in front of Mr. Rockefellow's retail coal office in Canon City. This block, which was obtained from the Santa Fe mine No. 5, now the Nonac mine, had, according to report, been standing as an advertisement beside the street curb for sixteen years, protected from the weather only by a sheet of tin laid on its upper surface. The block was originally 5 feet high, this dimension being the thickness of the coal bed from which it was obtained, and 4 feet square on the base and top. When the writer examined the block in 1908 its height was still 5 feet, but it had lost from 6 to 8 inches from each side by spalling. Cubical checking was developed all over the surface of the block and two large cracks had cut nearly through it, necessitating a narrow band of iron around the block to prevent it from falling apart. The surface of the coal was somewhat dulled by the weather, but it was still black, without any whitening from the appearance of ash or the deposition of sulphur compounds.

The statements about the keeping quality of the Canon City coal apply with minor variations to the coal beds in the greater part of the field, from the lowest or Rockvale bed to the highest or Brookside bed. They do not apply so well to the coal of the southern part of the field, which is inferior in keeping quality. A large pile of coal at the Radiant mine, which had been exposed to the air for about four months in 1908, was slacking badly and deep checks had developed in the lump coal. About the lumps of coal there was much fine débris which had fallen from their surfaces. The miners stated that lump coal amounting to half of the lump coal originally in the pile could be obtained from it after this exposure to the weather. The Radiant coal bed is in the lower part of the Laramie formation, at an estimated distance of 200 to 250 feet above the Rockvale bed at the base of the formation. The cause of this slight inferiority of the coal from the south end of the field is not known. The coal is apparently not quite so hard as that from the north end of the field, but in jointing it is not noticeably different from the latter. The blocks cut down in mining at the south end of the field are considerably smaller than similar blocks in the northern mines. The coal seems to break much more easily along the bedding planes and also along the joint planes, but other factors may also enter into the problem. The writer does not intend to state that the coal of the southern part of the field is not a high-grade domestic fuel, but that it is not quite so good in keeping or weathering quality as most of the coal of this field.

There is considerable difference in the size of blocks cut down in mining in the different mines, owing partly to variance in mining methods and partly to inequality in the strength of the joints. Along the steep-dipping western limb of the syncline, from the Royal Gorge mine southward, intricate sets of closely spaced cross joints, meeting at acute angles, have been developed from the greater strain which the rocks have there undergone. In a few places the coal on the west side of the field is slickensided and crushed, but as a rule the joints show no evidence of slipping. Along this belt of nearly vertical and overturned beds large blocks of coal can not be obtained. The method of overhead stoping, required to work the steep beds, also lowers the percentage of lump coal obtained and increases the slack. Throughout the greater part of the field, however, the beds are nearly flat, dipping at angles of 2° to 5°, and large blocks are cut down in mining. In the Chandler mine the writer observed a block of coal which had just been undercut and shot down that had the following dimensions: Height, 4 feet 1 inch, being the full thickness of the bed at that place; width, 3 feet; length, 18 feet. This block was too large for handling, but by using wedges it was broken into smaller blocks. It well exemplifies the strength of the coal. Similar blocks of smaller size are the rule in most of the mines. Shooting is always necessary, as it is difficult even to cut a small channel across the coal in obtaining samples. As a result of the strength and hardness of the coal and of the difficulties with which it is broken along the wide-spaced rectangular joints, the percentage of lump coal obtained in most of the mines is large. In the northern part of the field the range in sizes of coal from gently dipping beds is as follows: Lump coal, 45 to 70 per cent; nut coal, 15 to 30 per cent; slack and pea, 15 to 40 per cent. In most of the mines a much better showing could be made if greater care were exercised in mining, but the introduction of large numbers of careless foreign workmen who are paid by the ton of run-of-mine coal makes it difficult to increase the percentage of lump coal. In the early days, when the miners were all Americans, the percentage of lump coal is said to have been greater.

The sulphur content of the coal is low, as shown in the table of analyses. In unweathered coal the sulphur forms iron sulphides that make thin yellow leaf-like plates and spots on the joints and, rarely, in the bedding planes. Pyritiferous concretions are almost unknown in this field. Within 50 feet of the surface the coal is veined with white stringers of gypsum and of iron sulphates derived from the weathering of the coal and the interaction of the sulphate solutions with calcium in the ground water.

Another feature of the weathering of the coal beds is their marked thinning out near the surface. Many coal beds that appear nearly fresh to the eye, except that the coal does not have its true luster, are reduced over 20 per cent in thickness by weathering. This is shown at a score or more of prospects, in which the coal does not have its full thickness within 10 to 25 feet of the surface. In the open cut on the Chandler bed in Alkali Gap a bed of coal which measured 6 feet, including partings, at a depth of 18 feet wedged out gradually to an 18-inch bed of coaly smut at the surface. At a depth of 6 feet, where to the eye the coal appeared but slightly weathered, its thickness was only 2 feet 6 inches. Prospecting in this field is not satisfactory unless carried to a depth of 15 feet or more, and surface measurements of coal beds on the outcrop are unreliable.

ECONOMIC CONDITIONS.

The larger mines are reached by spurs of the Denver and Rio Grande and the Atchison, Topeka and Santa Fe railroads. The principal markets for the coal are in California, Kansas, Nebraska, Oklahoma, and Texas. Denver and other Colorado cities consume a minor part of the production. In July, 1908, the lump coal of one mine in the northern part of the field was being sold for $3.25 a ton f. o. b., and equally good lump coal of another mine was sold for $2.75 a ton f. o. b. The slack and pea coal are sold together at 50 to 90 cents a ton at the mines, depending on the amount of ash and on local freight rates. Most of this fine coal is used in factories and power plants in the adjacent territory.

The laborers employed in the mines are largely foreigners, among whom Italians are the most numerous. For piecework the miners receive the usual prices paid in this section of the Rocky Mountains, 45 to 85 cents a ton, depending on the difficulty of mining, the use of machines, etc. The workmen are not well organized, and there has been only one strike, about six years ago, when labor troubles caused many of the mines to close. As already stated, the mine managers report that the introduction of large numbers of foreign workmen has diminished the percentage of lump coal in the product, and in one mine it is proposed to pay the miners a premium based on the percentage of lump coal they produce.

The coal land in this field has all passed from the control of the Government to private and corporate ownership. In recent realty transfers the prices have ranged from $40 to $200 an acre, the higher price having been paid for excellent land tributary to a developed mine.

SUMMARY.

The Canon City coal field is a small syncline of the Laramie formation, located in south-central Colorado, at the foot of Wet Mountain, which is the eastern range of the Rocky Mountain system in this region. The eastern limb of this syncline dips westward at angles of 2° to 5°, except at the northern margin, where the dips are 5° to 15° S. This limb is broad in comparison with the western limb, being 2 to 4 miles wide and about 12 miles long. It contains all the larger mines of the field, eight in number, that ship by rail. The western limb of the syncline is a narrow belt of nearly vertical or overturned strata, not more than 1,000 feet wide. The mines on this limb are small, only two of them having railroad connections, but the Nonac mine, located at the northwest corner of the field, in the axis of the syncline, formerly produced about 300 tons a day.

The coal is a high-grade domestic fuel. It is bituminous, noncoking, and comparatively clean to handle. Its calorific value ranges from 11,000 to 12,000 British thermal units, the lower values characterizing the coal of the southern part of the field; all of that of the northern part exceeds 11,600 British thermal units. The keeping quality of the coal is excellent.

THE TRINIDAD COAL FIELD, COLORADO.

By G. B. Richardson.

INTRODUCTION.

LOCATION.

The Trinidad field is part of a large coal-bearing area, known as the Raton Mountain or, preferably, the Raton Mesa coal region, that lies along the eastern base of the Front Range in Colorado and New Mexico. The state boundary line divides this area into two approximately equal parts, the New Mexico portion being known as the Raton field and the Colorado portion as the Trinidad field. Although topographically, geologically, and economically the region as a whole is a unit, for descriptive and statistical purposes the twofold division based on political boundaries is convenient and has long been in use. The Raton Mesa region is one of several disconnected coal-bearing areas along the eastern front of the Rocky Mountains in Colorado, including the Denver, Colorado Springs, and Canon City fields. The coal in all these fields occurs in the "Laramie" formation, which formerly occupied a much greater region than at present; probably all the fields were once continuous, but as a result of structural disturbance and erosion they have been separated into the present detached areas.

PREVIOUS WORK.

The first systematic study of the geology of the Trinidad coal field was made by F. M. Endlich,[a] of the Hayden Survey, in 1875.

John J. Stevenson,[b] in connection with the work of the Wheeler Survey, reexamined a portion of the area in 1878–79.

Ten years later Arthur Lakes[c] published an account of this region in a report of the Colorado School of Mines.

In 1893 R. C. Hills included an account of the Trinidad field in his paper on the coal fields of Colorado,[d] and this was followed

[a] Ninth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1877, pp. 192–206.
[b] Rept. U. S. Geog. Surveys W. 100th Mer., vol. 3, Supplement, 1881, pp. 102–225.
[c] Trinidad or Raton coal fields: Ann. Rept. Colorado School of Mines, 1889, pp. 87–112.
[d] Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, pp. 324–331.

by the admirable series of reports, the El Moro, Walsenburg, and Spanish Peaks folios of the Geologic Atlas of the United States, by the same author.

In 1902 L. S. Storrs [a] briefly reviewed the results of Hills's work in the Trinidad field.

A number of shorter papers relating to the Trinidad field, chiefly technologic, are listed below:

HOSEA, R. M. Coal washing, a description of the Colorado Fuel and Iron Company's washery at Sopris, Colo. Mines and Minerals, vol. 17, 1897, pp. 478, 479, 521–524.

——— The Primero mines. Mines and Minerals, vol. 24, 1904, pp. 521–526.

——— Tercio and Cuatro mines. Mines and Minerals, vol. 25, 1904, pp. 218–223.

——— Segundo coke plant. Mines and Minerals, vol. 25, 1905, pp. 4–10.

LAKES, ARTHUR. Coal fields of Colorado. Mines and Minerals, vol. 19, 1899, pp. 541–543.

——— Aguilar coal and oil district. Mines and Minerals, vol. 23, 1903, pp. 196–198.

——— The Occidental and other coal mines of Huerfano County, Colo. Mines and Minerals, vol. 25, 1905, pp. 473–474.

——— Coals of the southern Colorado or Walsenburg and Trinidad region. Mining Report, vol. 51, 1905, pp. 234–255.

MEADE, FRANK. Coal mines of Pictou, Colo. Mines and Minerals, vol. 21, 1900, pp. 1–3.

McLAUGHLIN, J. E. Barella Mesa coal field. Mines and Minerals, vol. 24, 1904, p. 139.

WHITESIDE, F. W. The Delagua mines. Mines and Minerals, vol. 29, 1909, pp. 317–319.

Valuable data are also contained in the biennial reports of the state mine inspector.

PRESENT WORK.

Considering that the Trinidad field is so well known, another, which is not a final report, might seem superfluous. There has been, however, an increasing demand for information concerning this field, in connection with the sale of public lands, and because in the previous work no attempt was made to locate the coal outcrops with reference to land subdivisions there has been no satisfactory basis for the classification of the area. A reexamination of the field therefore became necessary, and a party consisting of J. H. Gardner, D. E. Winchester, O. J. Bowman, J. B. Mertie, and the writer spent three months of the season of 1908 in the field, the primary object being to collect data on which to base the classification and valuation of the public coal lands. The work consisted chiefly in locating the outcrop of the principal coal beds with reference to government corners, measuring the thickness of coal beds, and obtaining samples of coal for analysis. In addition fossils were collected, and such attention as was possible under the conditions of the work was devoted to the general geology of the region.

[a] The Rocky Mountain coal fields: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1902.

The location of the coal outcrops shown on the map (Pl. XX) was determined by plane-table stadia traverse, on a field scale of 2 inches to the mile, based on the few government corners which were found in the vicinity of the coal outcrops, and which are believed to be authentic. These are shown on the map by small circles. In some areas official resurveys must be made before the correct location of the coal outcrop can be established. There has been much contention over the location of government corners in this field, especially contiguous to the coal outcrop, and the condition of the land surveys is notoriously poor. It appears that in parts of the area corners were never officially established, and it is well known that some original monuments have been removed and that some corners have been illegally set. The network of sections and townships shown on the map is constructed according to data of the General Land Office and indicates a regularity throughout the field which probably does not exist.

A final report on this field must be postponed until the area is adequately surveyed, until the perplexing question of the age and correlation of the coal-bearing rocks is determined (which in turn must await more complete general knowledge of late Cretaceous and early Eocene paleobotany), and until the interior of the basin has been exploited with the drill.

ACKNOWLEDGMENTS.

The writer gratefully acknowledges the cordial cooperation in the prosecution of his work of the officials of practically all the mining companies in the Trinidad field. A considerable mass of information, consisting of mine maps, diamond-drill records, etc., was placed at his disposal for study, but for business considerations much of this information has been withheld from publication. Thanks are especially due to Messrs. R. C. Hills, of the Victor Fuel Company; E. H. Wietzel, of the Colorado Fuel and Iron Company; J. D. Skinner, of the Northern Coal and Coke Company; F. Guiterman, of the Carbon Coal and Coke Company; and E. E. Shumway, of the Rocky Mountain Fuel Company.

RELIEF AND DRAINAGE.

The Raton Mesa coal region occupies a hilly country east of the Rocky Mountains at the border of the Great Plains and Cordilleran provinces. In the Colorado portion of the region—the Trinidad coal field—the surface elevations of the greater part of the area range from about 6,000 feet along the eastern margin to more than 9,000 feet above sea level at the west end of the field. Near the western border the Spanish Peaks, two conical mountains composed of igneous rocks which rise abruptly above the surrounding area and culminate in an elevation of 13,623 feet, are the dominating feature of the topography. At the southeast end of the field the lava-capped Raton Mesa, consisting of a number of dissected table-lands, rises to an altitude of about 11,000 feet. Fishers Peak, an outlying remnant of the mesa, is the most conspicuous landmark in the immediate vicinity of Trinidad.

The main portion of the Trinidad coal field occupies a dissected upland area which is the northern continuation of the Raton Hills of New Mexico. East of the coal field a desert plain stretches as far as the eye can see, and immediately west of the field is the lofty Sangre de Cristo Range, the Front Range of the Rocky Mountain system in this latitude. On the north the surface gradually slopes down to the lowland at the base of Wet Mountain.

The topography of the coal field is directly related to the character and structure of the underlying rocks, which, as described below, consist generally of almost flat-lying beds of sandstone and shale and local masses of igneous rocks, including stocks, dikes, sills, and lava flows. The conspicuous highlands are formed of hard igneous rocks from which the associated softer strata have been eroded. The surface of the larger part of the area is composed of a series of disconnected flat-topped benches or stratum planes that rise in altitude steplike toward the west. The eroded ends of the benches form cliffs which are composed of the outcropping edges of beds of hard sandstone. The benches are underlain and upheld by sandstone from which the softer beds that now form the slopes of the next higher benches have been eroded.

Along the eastern and western margins of the field, where the inclination of the rocks is greater than in the interior, dip slopes are developed on the harder beds and an interrupted line of sandstone cliffs separates the coal field from the surrounding lowland areas that are underlain by shale. East of the coal field the lowland extends for many miles as an almost unbroken plain; but on the west, where the dip of the rocks is much steeper, the shale outcrops in a narrow belt of lowland, west of which beds of underlying sandstone form hogbacks at the base of the Sangre de Cristo Range. The most conspicuous line of hogbacks, locally known as the Stonewall, is composed of Dakota sandstone standing almost perpendicularly and extending parallel to and a few miles west of the coal field throughout its length.

The drainage of the Colorado portion of the Raton Mesa coal region is tributary to Arkansas River and that of the New Mexico portion to Canadian River, the divide being not far from and generally south of the state boundary line. The chief streams in the Colorado field are Purgatory and Cuchara rivers, which rise in the Sangre de Cristo Range and flow northeastward across the field independently of the local structure. A small portion of the extreme north end of the

Trinidad field drains into Huerfano River. A number of smaller streams radiate northward and southward from the Spanish Peaks, most of which are tributary either to the Purgatory or to the Cuchara. Apishapa River, the main stream that rises in the Spanish Peaks, flows northeastward directly into Arkansas River. The cliffs along the eastern margin of the coal field are drained through a number of short canyons. Only Purgatory and Cuchara rivers flow perennially, and the discharge of these is small, especially in the eastern portion of the field; the others, except during floods, are dry for the greater part of the year.

The valleys of the larger streams are fringed with well-developed terraces, which descend in altitude with approximately the grade of the streams and merge into broad débris-covered benches along the base of the cliffs at the eastern margin of the field. The river terraces are capped with a cover of sand and gravel ranging from 5 to 20 feet in thickness, resting on bed rock which outcrops in the sides of the valleys above the flood plains. The marginal benches are particularly conspicuous in the vicinity of Trinidad, where they are well developed at three distinct levels.

ACCESSIBILITY.

The Trinidad coal field is easily accessible and is reached by several important railroads. The Atchison, Topeka and Santa Fe Railway enters the field at Trinidad and passes up North Raton Creek on its way over Raton Pass. The shale lowland at the eastern base of the coal field is traversed by the Colorado and Southern and the Denver and Rio Grande railroads, each of which taps the coal field by several branch lines. The Denver and Rio Grande crosses the west end of the area between Walsenburg and La Veta, and a branch of that road extends around the northern coal outcrop between Walsenburg and Tioga. The Colorado and Wyoming Railroad, controlled by the Colorado Fuel and Iron Company, was built up Purgatory Valley between Trinidad and Tercio for the express purpose of developing the coal field. Any part of the Trinidad coal field can be reached by rail, although locally in the western part relatively steep grades will be encountered.

DESCRIPTIVE GEOLOGY.

GENERAL STATEMENT.

The rocks of the Trinidad coal field form an unsymmetrical syncline which is one of several basins that extend along the eastern front of the Rocky Mountains. The strata along the western limb of the fold dip steeply eastward, those along the eastern limb dip gently westward, and in the center of the basin the strata lie almost flat.

The coal-bearing rocks, as in all the fields throughout the Colorado portion of the Rocky Mountain region, are of Upper Cretaceous age and in the Trinidad field are members of the "Laramie" formation. These rocks are overlain by early Tertiary beds and underlain by a great mass of Cretaceous and older strata. Rocks of early Mesozoic and Paleozoic age outcrop on the Sangre de Cristo Range and underlie the coal field to a depth of many thousand feet. The Trinidad field has been the seat of profound igneous activity, the evidences of which are found in the great intrusive bodies which form the Spanish Peaks, in the marvelous system of dikes which radiate from this eruptive center, and in the lava-capped Raton Mesa.

STRATIGRAPHY.

GENERAL SECTION.

The following table summarizes the sedimentary rocks associated with the coal measures of the Trinidad field, the formation names being those used by R. C. Hills.

Geologic formations in Trinidad coal field.

System.	Series.	Group.	Formation.	Thickness (feet).	Description and occurrence.
Tertiary.	Eocene.		Huerfano.	1,500+	Coarse and fine grained red feldspathic sandstone on the flanks of West Spanish Peaks.
			Unconformity		
		Shoshone.	Poison Canyon and Cuchara.	2,000±	Massive beds of usually coarse-textured feldspathic sandstone; lower beds of conglomerate; subordinate interbedded drab shale. Outcrop in central highland area of coal field and on flanks of Spanish Peaks.
			Unconformity		
Cretaceous.	Upper Cretaceous.		"Laramie."	1,000 to 3,000.	Alternating beds of fine-textured buff feldspathic sandstone and drab sandy and clay shale containing workable beds of coal in the lower part. A variant bed of conglomerate occurring locally about 200 feet above the base of the formation occupies the greater part of the surface of the Trinidad coal field and underlies the entire area.
		Montana.	Trinidad sandstone.	150 to 225.	Massive fine-grained feldspathic sandstone lying between thinner-bedded sandstone and shale by which it merges into the overlying and underlying formations. Outcrops in conspicuous cliffs at the base of the coal measures.
			Pierre shale.	1,000+	Drab clay shale containing lenses of impure limestone. The Pierre shale underlies the coal basin and outcrops in a lowland belt east, north, and west of the Trinidad field.

UPPER CRETACEOUS.

PIERRE SHALE.

The Pierre shale has a wide distribution in the Great Plains region and outcrops in many disconnected areas along the base of the front ranges of the Rocky Mountains. In the Trinidad coal field it underlies the syncline of coal-bearing rocks outcropping along the eastern, northern, and western margins of the basin. On the west, where the dip of the rocks is steep, the shale occupies a narrow lowland belt at the base of the Sangre de Cristo Range; on the north, in the vicinity of Huerfano River, where the dips flatten out and the axis of the syncline rises, the shale outcrop occupies a wider zone; and along the eastern margin of the basin, where the strata lie almost flat, the Pierre underlies the broad plain that extends far to the east of the coal-measure cliffs.

In the area under consideration the Pierre is a mass of homogeneous drab clay shale more than 1,000 feet thick, the monotony of which is varied only by the presence of local thin lenses of limestone. The shale is underalin by a number of other Cretaceous and older formations, which need not be considered here, and it merges into the overlying Trinidad sandstone. The transition to the overlying rocks is gradual and is marked by a change from shale to sandstone through intermediate beds of sandy shale and thin-bedded sandstone. (See fig. 4.)

The following fossils, determined by T. W. Stanton, were collected in 1908 from the upper part of the Pierre shale at different localities in the Trinidad field: *Inoceramus sagensis* Owen, *I. cripsi* var. *barabini* Morton, *I. vanuxemi* M. and H.? *Baculites ovatus* Say, *B. compressus* Say, *Ostrea* sp.

The following forms were collected by T. W. Stanton and the writer in the shale 1¾ miles east of Monson, on the Colorado and Southern Railway, about 1,000 feet below the Trinidad sandstone: *Ostrea pellucida* M. and H., *Inoceramus vanuxemi* M. and H.?, *Cucullæa* sp., *Lucina* sp., *Volutoderma* sp., *Scaphites nodosus* Owen var. Doctor Stanton reports that these fossils indicate the Pierre shale of the Arkansas Valley and the Denver Basin.

TRINIDAD SANDSTONE.

The Trinidad sandstone is a relatively thin but important formation that lies between the Pierre shale and the coal-bearing rocks. It is remarkably persistent and outcrops around the margin of the basin in conspicuous ledges. Its importance is due to the fact that it almost immediately underlies the principal group of coal beds and, being readily recognizable, is a valuable aid in prospecting. The outcrop is particularly conspicuous along the eastern margin of the field and is typically developed in the vicinity of Trinidad, where the sandstone forms a prominent bench about 200 feet high, below which are slopes of Pierre shale. This bench, locally dissected by streams, is the most conspicuous topographic feature of the eastern margin of the coal field between Trinidad and Walsenburg. Along the western margin of the field the Trinidad sandstone is much less prominent, though it is locally well exposed, and at the north end, where the topography is more subdued than farther south, the formation is inconspicuous.

The Trinidad sandstone, as defined by Hills, consists of a lower zone of thin-bedded, fine-grained gray sandstone, the layers of which are separated from one another by thinner partings of shale, and an upper zone of massive light-gray sandstone which in places is capped by a few feet of brown sandstone in contact with the overlying coal measures. Locally a threefold division of the Trinidad sandstone is developed, a middle massive sandstone member, usually light colored, about 75 feet thick, lying between thinner-bedded sandstones and shales. The formation ranges from 150 to 225 feet in thickness. The sandstones are all fine textured and are composed of grains of quartz and feldspar in about equal proportions with a subordinate amount of mica, usually muscovite. In the upper beds of the formation there are well-developed ripple marks, worm tracks, and other indications of shallow-water conditions. The Trinidad sandstone is succeeded, apparently conformably, by carbonaceous shale and coal-bearing rocks and, as already stated, it grades downward into the Pierre shale. The formation is an off-shore deposit marking the transition from deep-sea to littoral conditions of deposition.

The lower portion of the sandstone contains marine shells of which the following collection, obtained by T. W. Stanton and the writer in the railroad cut east of the Pryor mine, near Monson station, is typical: *Ostrea* sp., *Ostrea pellucida* M. and H., *Chlamys nebrascensis* M. and H., *Avicula nebrascana* E. and S., *Inoceramus cripsi* var. *barabini* Morton.

This fauna is considered to be upper Montana by Doctor Stanton, who reports that although the last two species of the list range through a large part of the Montana group, the other two identified forms are known only from the upper Pierre and Fox Hills. The massive sandstone member of the formation is characterized by abundant remains of a seaweed which in the area under consideration is practically limited to the Trinidad sandstone. This fossil, *Halymenites major* Lesquereux, is pitted and cylindrical in cross section and is easily recognized.

"LARAMIE" FORMATION.

The Trinidad sandstone is conformably overlain by a mass of coal-bearing sandstone and shale which ranges in thickness from 3,000 feet at the west end of the field to 1,500 feet at the east end. The greater part of the surface of the coal field is occupied by these rocks, which outcrop in the area between the Trinidad sandstone escarpment and the highland surrounding the Spanish Peaks.

The sandstones are both thick and thin bedded, occurring locally in massive beds up to 50 feet thick but usually in layers ranging from 2 to 10 feet. They are fine textured and of a general buff tone but are in places gray, brownish, or almost white. Their composition is characteristically feldspathic and they consist of grains of quartz and feldspar in about equal proportions with occasional flakes of white mica. The shale is usually of a drab or grayish color but contiguous to coal beds is in many places black. The beds range from a fine clay shale to those with varying admixtures of sand grading into sandy shales or shaly sandstones. The succession of the strata is extremely varied. No two sections are exactly alike and it is of common occurrence for a bed of massive sandstone to merge both vertically and horizontally into beds of thin sandstone or shale.

The occurrence of coal in the lower part of the formation is described at length below. No one bed has been found to persist for any great distance, but on the other hand the lowest group of coal beds, consisting of lenses of coal of workable thickness occurring in the lower 250 feet of the formation, is remarkably persistent and has been traced throughout the field. More varied upper beds of coal occur at different horizons up to about 1,200 feet above the top of the Trinidad sandstone, but above this horizon no coal has been found.

About 200 feet above the top of the Trinidad sandstone there occurs at various localities, but not throughout the field, a bed of conglomeratic sandstone which locally becomes a true conglomerate. The pebbles are composed of rounded bits of quartz which vary from a fraction of an inch up to 2 inches in diameter. The conglomerate is thicker and the pebbles are larger along the western margin of the field than in the eastern part. In the vicinity of Tercio, for instance, the conglomerate is 150 feet thick, whereas in the eastern part of the field not more than 20 feet of it has been observed and locally it fades away and disappears. In the vicinity of Trinidad and in other places no corresponding conglomerate has been found. (See fig. 4 and Pl. XIX.) It is noteworthy that the pebbles of this conglomerate in the Trinidad field so far as observed consist entirely of quartz, which is in marked contrast to the varied composition of the pebbles in the conglomerate at the base of the Poison Canyon formation.

The significance of the conglomerate in the Trinidad field remains to be determined. Occurring intermittently in the midst of coal-bearing rocks it may represent only a local change in conditions of deposition, or, as maintained by Lee,[a] for a conglomerate in the Raton field, presumably the same as the one just described, it may mark an unconformity contemporaneous with the post-Laramie unconformity of the Denver Basin. In the Trinidad coal field the post-Laramie uplift has been considered to be marked by the basal conglomerate of the Poison Canyon formation described below. The

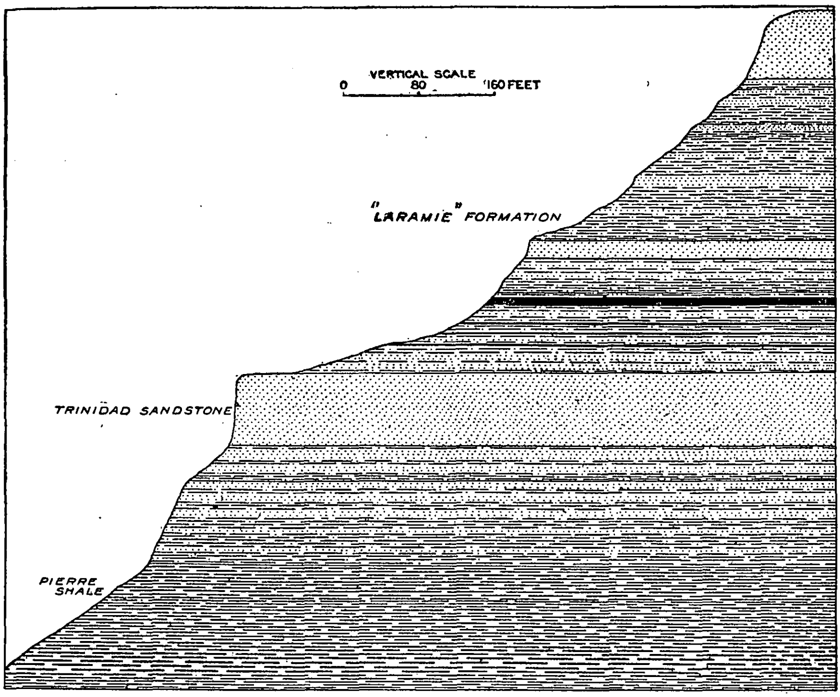


FIGURE 4.—Section of cliffs 4 miles north of Trinidad, Colo., showing transition from Pierre shale to Trinidad sandstone and lower part of "Laramie" formation.

final word concerning the age of the rocks above and below this conglomerate in the coal measures, involving its significance as a hiatus marker, must come from the paleontologist. Fossil shells occur very rarely if at all in these rocks, and the burden of proof falls on paleobotany. Fossil leaves are abundant and considerable numbers were collected in 1908 with the hope of settling the problem.

In all 62 species of fossil leaves from the coal-bearing rocks of the Trinidad field have been identified by F. H. Knowlton, but of this number 20 are known only from the Raton Mesa region and therefore are of no value in correlation, and of the remaining 42 species 15 are

[a] Lee, W. T., Bull. Geol. Soc. America, vol. 20, 1909, pp. 357-368.

known to have a wide range, occurring from the Montana to the Eocene. Only 12 species are also found in the Laramie of the Denver region. These figures are tentative, and until further paleobotanic knowledge is available the age of these rocks must remain unsettled. For the present it seems best to retain the old nomenclature and to refer the strata occurring between the Trinidad sandstone and the Poison Canyon formation to the Laramie.

EOCENE.

SHOSHONE GROUP (POISON CANYON AND CUCHARA FORMATIONS).

The "Laramie" formation in the Trinidad coal field is unconformably overlain by a group of rocks about 2,000 feet thick, consisting of conglomerate, sandstone, and shale, which R. C. Hills separated into the Poison Canyon and Cuchara formations, but which for present purposes may be considered together. These rocks, which commonly outcrop in conspicuous ledges, occupy the upland area at the base of the Spanish Peaks, approximately above the 7,500-foot contour.

On the western margin of the coal basin contiguous to the source of the material (the Sangre de Cristo Range) the lowest Eocene strata are composed of conspicuous beds of conglomerate and intervening beds of coarse sandstone. The conglomerate is made up of rounded pebbles and bowlders up to 3 feet in diameter, consisting of granite, gneiss, quartzite, and a variety of porphyritic igneous rocks. The pebbles decrease in size and abundance toward the eastern part of the field. Scattered pebbles of granite and quartzite, however, occur in coarse-grained sandstones along the eastern contact, although in that part of the field in general it is difficult to draw a sharp line of demarcation between the Eocene and the underlying "Laramie." In the northern part of the field, however, there is a distinct overlap of the younger rocks upon the older, which completely conceals the probable continuation of the coal field toward Huerfano Peak.

The sandstones are generally buff in color, but locally are gray and in places weather to a slight pinkish tinge. They are composed of grains of quartz, feldspar, and mica. The finer-textured varieties closely resemble the underlying sandstones of the "Laramie" formation but the presence of local pebbles of granite, quartzite, etc., generally serves to distinguish them. The shale, which is yellow to drab in color and variously composed of clay and sand, is of subordinate occurrence and probably constitutes only about a third of the group.

Hills found no fossils in these beds, but because of their stratigraphic position considered that they were probably equivalent to the post-Laramie deposits of the Denver Basin. In 1908 several collections of leaves were obtained from sandstones near the base of this group of rocks, which Knowlton states are of Denver age, thus confirming Hills's conjecture.

The name Shoshone group [a] has recently been proposed to include those rocks which unconformably succeed the "Laramie" and which are overlain by the Fort Union or Wasatch beds where they are present. The Poison Canyon and Cuchara formations therefore belong to the Shoshone group.

HUERFANO FORMATION.

The somber, buff-colored beds which have just been described are overlain, presumably with unconformity, by a mass of red beds at least 1,200 feet thick, which Hills has named the Huerfano formation. The type locality is in Huerfano Park,[b] only a few miles northwest of the north end of the Trinidad coal field, the probable former connection of the beds in the two areas having been severed by erosion. In the Trinidad coal field the Huerfano formation occurs only on the flanks of West Spanish Peak, where at least 1,200 feet of red beds are exposed. The beds consist of coarse red feldspathic sandstone and red sandy shale which locally are mottled with green specks.

No fossils have been found in these rocks adjacent to Spanish Peaks, but their occurrence and physical appearance leave little room for doubt that they are part of the Huerfano formation, which is so well developed in Huerfano Park. In the Huerfano Park beds Hills, Osborn, and Wortman have collected a number of fossil bones, from which Osborn concludes[c] that the "formation began during the Wind River and continued without a break into the period of the lower Bridger."

In connection with the survey of the Trinidad coal field a reconnaissance was made in Huerfano Park and a few fossil bones were collected, among which J. W. Gidley, of the United States National Museum, reports the presence of *Crocodilus* sp. ?, *Baptemys* sp. ?, *Coryphodon* sp., and *Oxyæna morsitans* ?, and states that the two last-named genera, so far as known, have been found only in the Wasatch. To judge from this statement, and from the fact that the Wasatch formation where well developed west of the Rocky Mountains is characteristically red, it appears that the Huerfano formation may also be in part Wasatch.

IGNEOUS ROCKS.

Igneous rocks occur abundantly in the Trinidad coal field and are of importance, not only in connection with the general geology of the region, but because they have a direct economic bearing on the value of the coals.

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[a] Cross, Whitman, Proc. Washington Acad. Sci., vol. 11, 1909, pp. 27-45.

[b] Hills, R. C., Recently discovered Tertiary beds of the Huerfano River basin, Colorado: Proc. Colorado Sci. Soc., vol. 3, 1889, pp. 217-223.

[c] Osborn, H. F., Cenozoic mammal horizons of western North America: Bull. U. S. Geol. Survey No. 361, 1909, p. 48.

The Trinidad field has been the seat of great igneous activity at different times since the deposition of the Huerfano formation in the early part of the Eocene period. Masses of igneous rock of various composition have been intruded into the strata, and flows of lava have been poured out on the surface, resulting in very complex igneous phenomena.

The intrusion of the great stocks that form the core of the Spanish Peaks must have destroyed a considerable volume of coal with which the molten rock came into contact, and the effect of the heat probably exerted a considerable metamorphosing influence on a still larger mass. But because of the great depth beneath the surface of the principal coal beds in the vicinity of the peaks such effects probably

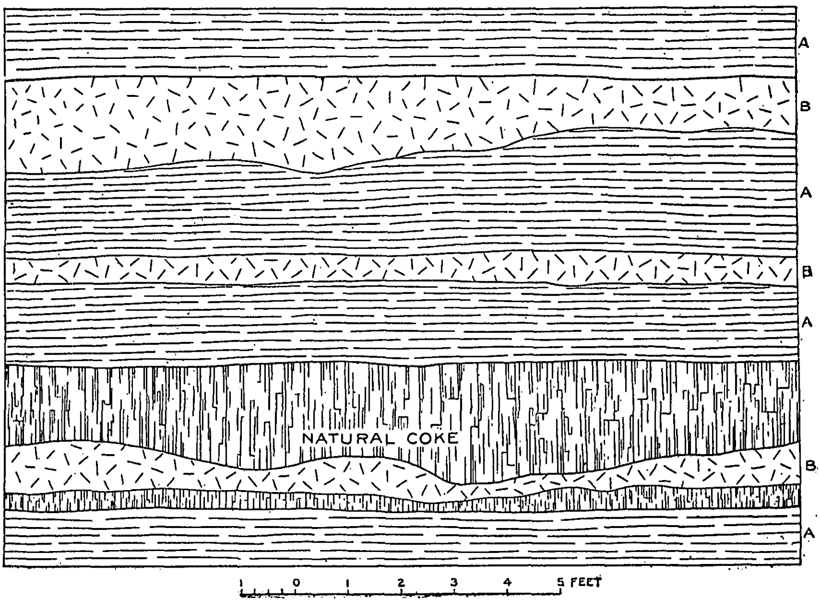


FIGURE 5.—Sills of igneous rock in "Laramie" formation and bed of natural coke, in Purgatory Valley, opposite Sopris Plaza, near Trinidad, Colo. A, Shale; B, sill of igneous rock.

are of little practical importance. In connection with the intrusion of the main Spanish Peaks stocks there was developed a system of dikes, which, centering in the peaks, radiate for several miles from them in all directions;[a] and a great system of sills also originated in the main centers of eruption. The dikes are more or less vertical masses of igneous rock only a few feet thick which have cut across the strata, and are of great length compared with their thickness. Where a dike has come into contact with a bed of coal the coal has been metamorphosed by the heat of the molten igneous rock into natural coke. But as a general rule the metamorphism has not proceeded much farther into the coal bed than a distance on each

[a] See folios 68 and 71, Geol. Atlas U. S.

side of the dike about equal to its own thickness. Dikes have been encountered in a number of mines, and though they are hard to cut through they present few other practical difficulties. On the other hand, the sills, which are more or less nearly horizontal masses of igneous rock, usually only a foot or so thick but of enormous width compared with their thickness, have been intruded along the bedding planes and between the strata instead of cutting across the beds like dikes. Consequently, wherever a sill has been intruded along a bed of coal the latter has been converted to natural coke over a large area. (See fig. 5.)

The location of the principal dikes and sills in the Trinidad coal field is shown in the maps of the Spanish Peaks and Walsenburg folios, but of course the existence of sills that do not outcrop can be determined only by drilling or actual mine work.

The great lava flows on Raton Mesa are far above the coals and appear to have had practically no effect on them. But possibly some of the lava flows are directly connected with conduits beneath them, and if so the coal in the immediate vicinity of the intrusive rocks has doubtless been metamorphosed. Intrusive masses in the Raton Mesa will probably be discovered in the progress of mining.

STRUCTURE.

The rocks of the Trinidad coal field form an unsymmetrical fold, named the Spanish Peaks syncline, the axial trend of which is northwest-southeast. At the north this fold merges into the Huerfano Park syncline and at the south, in the Raton field, New Mexico, according to Lee, the dips become less and the strata finally lie practically flat. The Spanish Peaks syncline is characterized by steep eastward dips, ranging from 20° to 90° on the western limb, and by low westward dips, ranging from 2° to 10°, on the eastern limb; while in a relatively broad area in the interior of the field the strata lie almost flat.

This comparatively simple structure is modified by local complications. Along the western margin the strike of the Dakota sandstone, which stands almost vertically and outcrops in the prominent hogback called the Stonewall, is distinctly curved. Between the Colorado-New Mexico boundary and Cuchara River the strike of the sandstone is northeastward, then northwestward, and again northeastward, the trend resembling a rude S-like curve. Conforming with this structure, the adjacent coal measures are similarly warped, as shown by the position of the coal outcrop. In a relatively narrow zone east of the Dakota hogback the western limb of the Spanish Peaks syncline is modified by local folds. At the southwestern margin of the basin, in the vicinity of Tercio, and at the northwestern margin, in the vicinity of La Veta, subsidiary anticlines and synclines are developed. (See pp. 418 and 422.)

At the north end of the coal field the Wet Mountain uplift has so warped the strata that the rocks northwest of Walsenberg form a southward-plunging syncline, and farther northwest, at the south end of Huerfano Park, the strata swing around so as to conform to the normal southwesterly dips of the main basin.

In the vicinity of Morley, in the southern part of the field, a disturbance has domed the strata and brought up the Pierre shale and Trinidad sandstone in the midst of the basin. This fold is a narrow, elongated dome, the axis of which strikes northwest and southeast, and which, measured by the outcrop of the exposed Pierre shale, is about a mile long and half a mile wide. The strata dip away on all sides from the center at angles averaging about 10°. Other structural irregularities are noted below.

In the valley of Guajatoyan Creek, above the mouth of Coal Creek, in the western part of the field, where the strata for the most part dip eastward, there is a belt of westward-dipping rocks which is probably caused by faulting.

Between Segundo and Sopris the impossibility of tracing the coal beds across Purgatory River suggests the presence of a fault.

About 5½ miles up Reilly Canyon from its mouth there is a bed of massive sandstone well exposed along the roadside lying almost flat on thin-bedded sandstone and shale that are tilted at an angle of about 20°. These conditions were observed only in this one locality. Cross-bedding may possibly account for these relations, but a local unconformity is strongly suggested. The horizon is about 600 feet above the Trinidad sandstone.

Northwest of Aguilar a local flexure of the strata causes abnormally steep dips in a narrow zone in which the Green Cañon mine is located.

In the vicinity of Santa Clara Creek, near the eastern margin of the field, a number of small normal faults are present, as described on page 413.

Details of structure are given below in connection with descriptions of the occurrence of the coal.

THE COAL.

PRELIMINARY NOTE.

In the description of the coal, the field is divided for convenience into the following divisions: Eastern outcrop, including the Trinidad and Walsenburg districts; western outcrop, including the La Veta, Stonewall, and Tercio districts; and interior of the field, including the Morley and Purgatory districts and undeveloped areas. In following the description it will be of assistance to refer to the diamond-drill sections, Plate XIX, and the map, Plate XX. The diamond-drill sections were plotted from records furnished by several mining companies. The sections show graphically the stratigraphy of the coal-bearing rocks and emphasize the variance in the occurrence of the coal beds. The holes are distributed along the eastern margin of the field, 26 being in Las Animas and 6 in Huerfano County, but at the request of the mining companies the locations of the holes are not given. The map, in addition to showing the location of the mines and the outcrop of the principal coal beds, also shows the approximate depth of the Trinidad sandstone beneath the surface. This information was obtained by combining structure contours drawn to the Trinidad sandstone with topographic contours. Although from the nature of the case the boundary lines separating the areas of different depth shown on Plate XX can not be exact, they are nevertheless in general believed to be close approximations. The most doubtful areas are in the interior of the field where little information is available.

EASTERN OUTCROP.

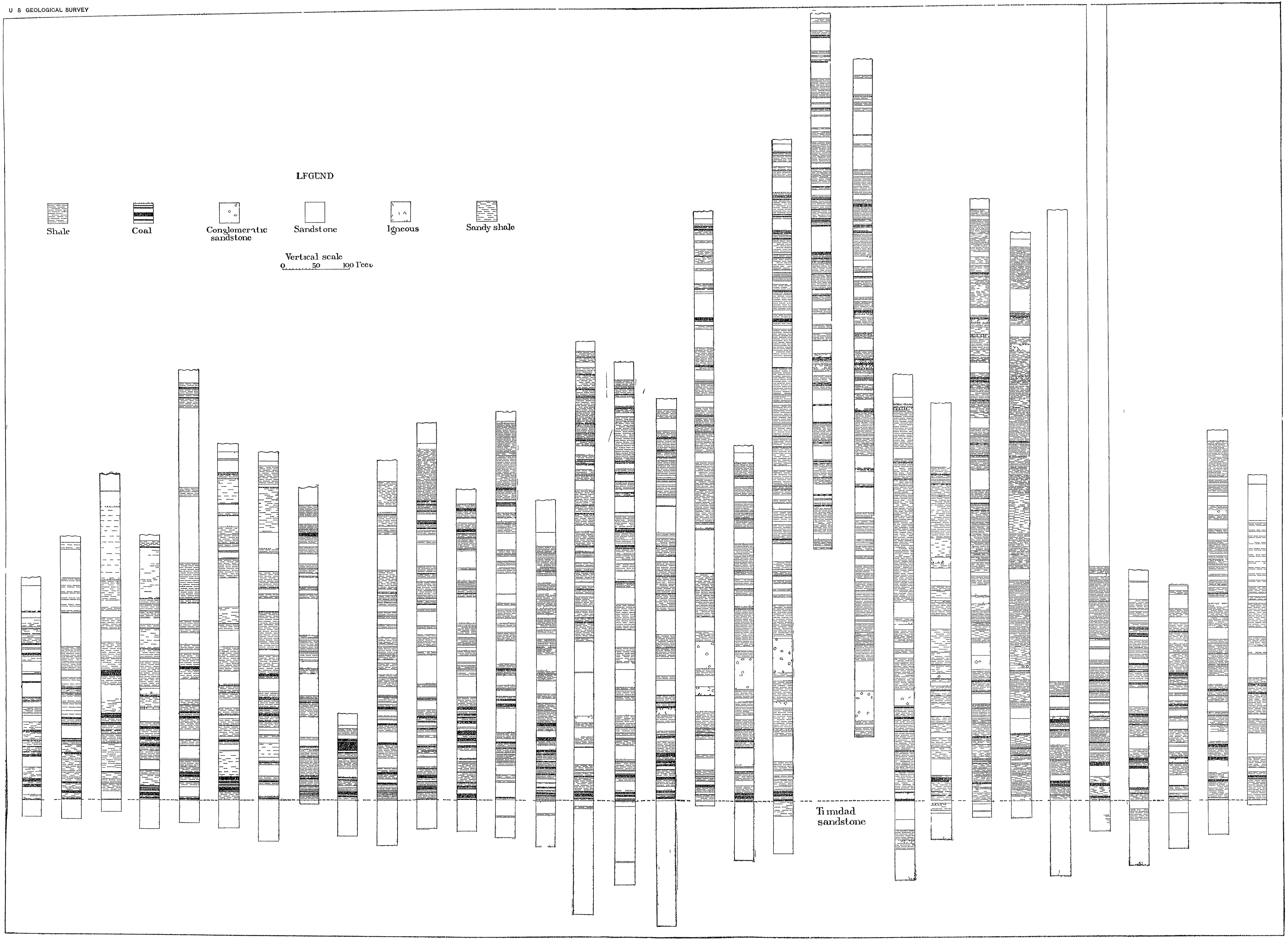
The eastern part of the Trinidad coal field is divided into the Trinidad and Walsenburg districts, named from the principal town in each. The difference in the character of the coal in the two districts makes the division a natural one, although the transition from a coking coal in the south to a noncoking coal in the north is too gradual to permit the drawing of a sharp division line between them; nevertheless, the boundary between Las Animas and Huerfano counties is generally considered as separating the districts.

TRINIDAD DISTRICT.

GENERAL CONDITIONS.

The Trinidad district includes the area contiguous to the outcrops of coal along the eastern margin of the field between the Colorado-New Mexico and the Las Animas–Huerfano County boundary lines.

For a distance of 15 miles northwest of the state boundary the "Laramie" outcrops in the steep slopes of Raton Mesa. The mesa is capped by flows of basaltic lava lying on the coal-bearing rocks, and the Pierre shale outcropping beneath cliffs of Trinidad sandstone underlies the plain at the base of the mesa. Erosion by Purgatory River and its tributaries has caused a deep embayment of the coal outcrops, which extend around the northern slopes of Raton Mesa, so that the lowest coal bed passes beneath the broad valley near Sopris, 4 miles southwest of Trinidad. Purgatory Valley is broad and open and is bounded by sandstone cliffs.



DIAMOND DRILL RECORDS, TRINIDAD COAL FIELD, COLORADO, SHOWING LOWER PART OF THE LARAMIE FORMATION AND THE VARIED CHARACTER OF THE COAL BEDS

At the request of the owners the location of the drill holes is not given The holes are distributed along the eastern part of the field 26 in Las Animas County and 6 in Huerfano County

West and north of Trinidad the Trinidad sandstone forms a prominent bench bordered by an escarpment, below which are steep slopes of Pierre shale. The lowest group of coal beds outcrops in the slope immediately above and west of the Trinidad sandstone bench and can be readily located by the topography. Above the coal beds the country rises toward Spanish Peaks in a series of benches and intervening escarpments, the topography corresponding to the varying hardness of the underlying beds of sandstone and shale, which dip westward at a low angle. This area is much dissected by streams that head in Spanish Peaks and the outcrops of the coal beds are consequently intricately scalloped, extending up each valley and around the intervening divides.

The occurrence of coal in the Trinidad district will be described under three headings—the lower, middle, and upper groups.

LOWER COAL GROUP.

The lower group of coals is the most important and persistent in the entire field. It consists of one to eight workable coal beds which occur within a zone 250 feet thick above the top of the Trinidad sandstone. This coal group is present throughout the field, though in some places there are many more coal beds than in others and the beds are extremely varied in thickness. No bed has been traced for more than a few miles and it should not be assumed, without actual tracing, that a bed in one part of the district is necessarily the same as one occurring at the same distance above the Trinidad sandstone in another part of the district.

The following summary description of the occurrence and thickness of coal beds in the lower group in the Trinidad district begins at the south and proceeds in general northward.

Little is known of the coal in the extreme southeastern part of the Trinidad field between the state boundary and Gray Creek, although in the New Mexico area a number of mines are in operation and it is probable that Raton Mesa is underlain by a fine body of coal. In Colorado the thick accumulation of talus and the dense cover of vegetation along the northern slopes of the mesa has retarded prospecting and development. The Trinidad sandstone, however, outcrops in its usual conspicuous cliffs and can be readily traced. The broken line on the map shows the approximate location of the base of the coal-bearing rocks in this area. Between the New Mexico-Colorado boundary and San Francisco Creek, in T. 34 S., R. 62 W., this line was located by the party in charge of Willis T. Lee during his survey of the Raton coal field in 1908.

The southernmost locality along the eastern margin of the Trinidad field where coal has been developed is in the vicinity of Gray Creek, in the southeast corner of T. 33 S., R. 63 W., where the Gray Creek mine of the Victor Fuel Company (No. 4)[a] is located. Within a zone of 150 feet above the Trinidad sandstone in the vicinity of Gray Creek there are from two to six beds of coal more than 2 feet thick. A number of measurements show one good bed between 4 feet 2 inches and 5 feet 10 inches thick, and in a few sections a bed 13 feet 4 inches thick has been found. The coal worked in the Gray Creek mine is irregular in thickness, ranging between 4 and 14 feet. Partings of shale or sandstone in places separate the bed into several benches, but locally they disappear, leaving one thick bed of coal. Over much of the area worked in the Gray Creek mine there is a good sandstone roof, though in places the roof is shale. The floor is shale and locally causes trouble by heaving when the pillars are drawn. The coal bed lies almost flat and is worked from four drifts on the outcrop.

The Engle (No. 5) and Starkville (No. 10) mines of the Colorado Fuel and Iron Company are the oldest and largest in the Trinidad district. The workings of these two mines are connected, and together they cover an area of about 3½ square miles. The Engle mine is situated 3 miles northwest of Gray Creek and 2 miles southeast of Trinidad, on the northern slopes of Raton Mesa, below Fishers Peak, and is reached by a branch line of the Denver and Rio Grande Railroad. For a number of years coal from the Engle mine was coked in the ovens at Elmoro, 4 miles northeast of Trinidad. The mouth of the Starkville mine is situated on the main line of the Atchison, Topeka and Santa Fe Railway on the east side of North Raton Creek, 3 miles south of Trinidad.

The coal bed worked in the Engle and Starkville mines lies between 30 and 50 feet above the Trinidad sandstone and varies in thickness from 4 to 8 feet or more. At the entrance to the Engle mine the following section was measured:

Section of coal bed at entrance to Engle mine.

	Ft.	In.
Sandstone.		
Shale		8-12
Coal	4	
Shale, coaly		4
Coal	4	
Shale.		
Total coal	8	

It is reported that the average thickness of the bed in the Engle mine is between 6 and 7 feet, and that two partings of bony coal, each about 3 inches thick, usually separate the bed into three benches, although in places they disappear and leave a clean bed of coal. In

[a] Numbers in parentheses refer to locations on Plate XX.

some parts of the mine a bed of sandstone makes a good roof, but in other parts a "draw slate" appears between the sandstone and the coal, causing a poor roof. The floor is a sandy shale.

The following section was measured in room 6, entry G4, of the Starkville mine:

Section of coal bed in Starkville mine.

	Ft.	in.
Shale roof.		
Coal	3	2
Coal, bony		4
Coal		3
Coal, bony		2½
Coal	1	2
Coal, bony		2
Coal	1	11
Shale floor.		
Total coal	7	2½

The workings of the Engle and Starkville mines are being extended southward toward Fishers Peak. The deepest parts of the mines are now under a cover of approximately 1,100 feet, but owing to the rapid rise of the surface further extension of the workings toward Fishers Peak will carry them under a considerably greater thickness of cover.

Along the outcrop between the entrances to the Engle and Starkville mines there are three relatively small openings, known as the Newcomb, Bloom, and Abercrombie mines. At the Bloom mine (No. 7) of the Jeffreys Coal and Mining Company, the largest of the three, two beds are exposed about 90 feet apart, which measured as follows:

Section of coal beds at Bloom mine.

	Ft.	in.
Shale.		
Coal	1	6
Bone		8
Coal	5	
Shale.		
Interval	90	
Coal	3	2
Bone		5
Coal	1	3
Total coal	10	11

Coal from the Bloom mine is hauled in wagons to Trinidad.

The Engle-Starkville coal bed has not been traced far west of North Raton Creek, and a bed only a few feet above the Trinidad sandstone is worked at the Francisco (No. 12) and Piedmont (No. 13) mines of the Rocky Mountain Fuel Company. These are connected workings in sec. 34, T. 33 S., R. 64 W. In the Francisco mine the upper of two benches is worked and in the Piedmont the two benches are reported to come together and are mined as one.

Section of coal bed in Francisco mine.

	Ft.	in.
Shale.		
Bony coal		6
Coal		7
Shale		1½
Coal	2	2
Shale.		
Total coal	3	3

Section of coal bed in Piedmont mine.

	Ft.	in.
Shale.		
Coal		7½
Shale		1
Coal		9
Shale		1½
Coal	3	2
Total coal	4	6½

The partings are said to disappear and the coal is reported to be about 7 feet thick in the southwestern part of the Piedmont mine. West of the Piedmont mine this bed is not worked and the dip carries it beneath Purgatory River near the bridge north of Sopris.

In the vicinity of Sopris the lowest group of coals consists of a varying sequence of six or eight beds from 1 to 7 feet thick within a zone of 250 feet above the base of the formation. These coal beds thicken and thin out characteristically. The most important is the one worked at the Sopris mine (No. 15) of the Colorado Fuel and Iron Company. This bed is about 190 feet above the Trinidad sandstone, and the mine workings show that it varies considerably in thickness and contains a number of partings. The following section was measured in room 3, entry 17 west:

Section of coal bed in Sopris mine.

	Ft.	in.
Sandstone roof.		
"Iron slate"		8
Coal		3½
Coal, bony		4½
Coal		9
Coal, bony		1½
Coal		5½
Coal, bony		1½
Coal		8
Coal, bony		1
Coal		9
Shale.		
Total coal	3	7½

In part of the mine, as shown below, there is a good body of coal separated by a thin bed of sandstone, which in places is too thick to permit the economical working of the entire bed.

Section of coal bed in Sopris mine.

	Ft.	in.
Shale.		
Coal	2	2
Shale or bone		9
Coal		9
Sandstone		8
Shale or bone		6
Coal	4	3
Shale.		
Total coal	7	2

In the La Belle mine (No. 14) of the Rocky Mountain Fuel Company, at approximately the same horizon, the following section was measured:

Section of coal bed in La Belle mine.

	Ft.	in.
Shale.		
Coal	4	
Shale		6
Coal		6
Shale.		
Total coal	4	6

The McLaughlin mine (No. 22), near Purgatory River, is on a bed at about the same horizon. The coal bed in this mine measures as follows:

Section of coal bed in the McLaughlin mine.

	Ft.	in.
Shale.		
Coal	2	3
Coal, bony		4
Coal		9
Bone		3
Coal	1	9
Shale		1
Coal		7
Shale.		
Total coal	5	8

North of Purgatory River, near the mouth of Reilly Creek, the recently opened Cokedale mine (No. 23) of the Carbon Coal and Coke Company is on a bed in the lower coal group about 220 feet above the Trinidad sandstone. The position of this bed, therefore, corresponds approximately to that of the Sopris coal. The Cokedale bed varies considerably in thickness and has the reputation of being a dirty coal. The following section was measured in room 26, entry 4 west:

Section of coal in Cokedale mine.

	Ft.	in.
Shale.		
Coal, bony		5½
Coal	1	2
Coal, bony		4
Coal		8
Coal, bony		2½
Coal		11
Coal, bony		2
Coal		4½
Shale		4
Coal	1	6
Shale		4
Coal		10
Coal, bony		3½
Shale.		
Total coal	6	11

Between Cokedale and Trinidad there are a number of prospect pits on various beds of coal belonging to the lower group, but only a few small mines. So far as known, the coal is thinner here than in other parts of the field. The following measurements illustrate the conditions:

Sections of coal bed between Cokedale and Trinidad.

NE. ¼ sec. 28, T. 33 S., R. 64 W. (No. 17).

	Ft.	in.
Shale.		
Coal	2	2
Shale	1	2
Coal		8
Shale.		
Total coal	2	10

NE. ¼ sec. 16, T. 33 S., R. 64 W. (No. 18).

	Ft.	in.
Shale.		
Coal	2	4
Coal, bony		8
Shale		2
Coal, bony		4
Shale		3
Coal		5
Shale.		
Total coal	3	9

SW. ¼ sec. 10, T. 33 S., R. 64 W. (No. 19).

	Ft.	in.
Shale.		
Coal, bony		3
Clay		½
Coal, bony		5
Coal	1	3
Shale		4
Coal	1	9
Shale.		
Total coal	3	8

Keystone mine, NE. ¼ sec. 10, T. 33 S., R. 64 W. (No. 20).

	Ft.	in.
Shale.		
Coal		9
Bone		5
Coal		11
Shale		1½
Coal	2	2
Shale.		
Total coal	3	10

In the SW. ¼ sec. 2, T. 33 S., R. 64 W. (No. 21), the coal is 2 feet 10 inches thick and has a shale roof and shale floor.

North of Trinidad the coal beds are thicker and there are a number of important mines. Several prospects at the head of Powell Canyon, in the SE. ¼ T. 32 S., R. 64 W., show more than 4 feet of coal. At the Baldy, a small mine without railroad connection in the SE. ¼ sec. 23, T. 32 S., R. 64 W., the following section was measured:

Section of coal bed in Baldy mine (No. 51).

	Ft.	in.
Shale roof.		
Coal	3	2
Shale		3
Coal	1	1
Shale		3
Coal		11
Shale.		
Total coal	5	2

The Mount Pleasant, in the NW. ¼ sec. 36, T. 32 S., R. 64 W., is another small mine without railroad connection. The bed worked is about 80 feet above the Trinidad sandstone.

Section of coal bed in Mount Pleasant mine (No. 52).

	Ft.	in.
Shale roof.		
Coal and bone		3
Shale		4
Coal	2	10
Shale		2
Coal		8
Shale.		
Total coal and bone	3	9

The Bowen mine of the Victor Fuel Company, in secs. 24 and 25, T. 32 S., R. 64 W., is one of the large producers of the Trinidad field. The mine is situated on the Trinidad sandstone bench 300 feet above the camp, which is in the Pierre shale valley. The workings are reached by a gravity plane connected with the Colorado and Southern Railway.

Section of coal bed in Bowen mine (No. 54), room 11, entry 2 N. 6 E.

	Ft.	in.
Coal	3	8½
Shale		½
Coal	1	
Shale		1
Coal		10
Shale		3
Coal	1	1
Total coal	6	7½

The Suffield mine (No. 55) of the Green Cañon Coal Company occupies a position similar to that of the Bowen, being located on a bench a few hundred feet above the mining town at the base of the cliffs. This mine was not in operation when visited in 1908, and a section of the coal bed was not obtained. The mining camps at Bowen and Suffield are subject to the disadvantage of having no local water supply, and water for both camps is hauled by train from Trinidad.

Stream erosion has so dissected the coal measures in the northern half of T. 32 S., R. 64 W. that the outcrop of the beds is extremely intricate. A number of openings on the coal have been made in Tingley and Chicosa canyons, in which the Forbes (Cox) and Majestic mines are located. The coal bed here, as usual, outcrops in the slope above the Trinidad sandstone escarpment, necessitating the construction of gravity tramways to reach the mines. A branch of the Colorado and Southern Railway extends up Tingley Canyon to the tipple of the old Forbes property, now known as the Cox mine (Nos. 56–58), operated by the Chicosa Fuel Company.

The principal coal occurs about 50 feet above the Trinidad sandstone. The following measurements were made at the Cox mine:

Sections of coal bed at the Cox mines.

SW. ¼ sec. 10, T. 32 S., R. 64 W. (No. 58).

	Ft.	in.
Shale.		
Coal	5	1
Shale		2
Coal	2	2
Shale		10
Coal	1	9
Shale.		
Total coal	9	

NW. ¼ sec. 15, T. 32 S., R. 64 W. (No. 56).

	Ft.	in.
Shale.		
Coal	4	1½
Shale		6
Coal	1	8
Shale.		
Total coal	5	9½

The Majestic mine (No. 59) of the Continental Fuel Company was not being worked when visited in 1908, and the coal bed, which is the same as that worked at the Cox mine, was not measured.

Little is known of other beds in the lower coal group between Cokedale and Majestic. In that area, however, at least one workable bed appears to be everywhere present, although it varies considerably in thickness and position. North of the Majestic mine to the north end of the field two or more beds of workable thickness are known in the lower group, although generally at any locality only one is worked, and the beds thicken and thin out irregularly.

The Ludlow mine (No. 60) of the Huerfano Coal Company and the Greenville mine (No. 61) of the Cedar Hill Coal and Coke Company are situated on the bench above the Trinidad sandstone and are reached by gravity planes which connect with the Colorado and Southern Railway. Three beds are present in this vicinity, as shown by the following section at the Ludlow mine:

Section of coal beds in NW. ¼ sec. 32, T. 31 S., R. 64 W.

	Ft.	in.
Coal		6
Shale		½
Coal	2	3½
Interval	12–20	
Coal	5	

	Ft.	In.
Interval	44	
Coal	1	4
Shale		7
Coal	3	3
Shale.		
Interval	25	
Sandstone, Trinidad.		
Total coal	12	4½

The following measurement was made at the Greenville mine, which is on the lowest bed of the group:

Section of coal bed at Greenville mine (No. 61).

	Ft.	In.
Shale.		
Coal	1	
Shale		1
Coal	4	3
Shale.		
Total coal	5	3

In Road Canyon the Berwind and Tabasco mines are being worked by the Colorado Fuel and Iron Company, in conjunction with the coke ovens at Tabasco. These mines are located on the lowest bed of the lower coal group where it passes beneath the surface; farther up the canyon the same bed is being opened at the Toller shaft. The Trinidad sandstone is conspicuous in this region, and the coal beds occur in a zone of about 130 feet of shale and thin sandstone lying between the Trinidad and a massive bed of conglomeratic sandstone. Two beds are well developed here, but only the lowest is worked. The following section shows the local stratigraphy.

Section of rocks in Road Canyon at Tabasco.

	Feet.
Sandstone, massive conglomeratic, siliceous pebbles up to 1 inch.	20+
Shale and thin sandstone, including sill	60
Coal, Hastings bed (?)	8±
Shale and thin sandstone	60
Coal, Berwind bed	6±
Shale and thin sandstone	5–25
Sandstone, Trinidad.	

In the Berwind mine a parting of shale from half an inch to 6 inches thick usually occurs about 10 or 12 inches beneath the top of the coal bed, and the coal below the parting is reported to vary between 48 and 70 inches in thickness. In some places the roof is shale and in others it is sandstone. A prospect on the upper Hastings (?) bed above the Tabasco coke ovens shows 7 to 8 feet of good coal, but the bed has not been developed.

The Toller shaft (No. 64) of the Cedar Hill Coal and Coke Company is one of the few shafts in the Trinidad field and is an indication of the future development of the field. New exploitation will tend to be carried on by shafts by means of which the reserves of the interior of the field will be reached after the choice property along the coal outcrop has been taken up or exhausted. The Toller shaft, reported to be 360 feet deep, was sunk in 1908, but the mine was not in operation in that year.

Little is known of the coal between Road Canyon and Canyon de Agua, but in the latter is located the Hastings mine (No. 67) of the Victor Fuel Company, one of the important mines of the field. In the vicinity of Hastings the lower coal group consists of one to six varying beds of coal within a zone of 150 feet above the Trinidad sandstone, but at present only one bed is worked. The following section was measured in the Hastings mine:

Section of coal bed in Hastings mine.

	Ft.	in.
Shale.		
Coal	3	8
Sandstone		1
Coal	1	8
Shale.		
Total coal	5	4

The Hastings bed is reported to thin toward the west, and mining on it may have to be abandoned in that direction. Tests show that another bed, 40 feet beneath the Hastings, corresponding to the Berwind coal, has a thickness in this area of about 5 feet.

Little prospecting has been done for a few miles north of Hastings, but along Apishapa River the coals are better known. There the lower group consists of three to six varying beds of coal between 1 and 6 feet thick, but usually only one workable bed is known. This is named the Peerless bed, from the Peerless mine (No. 85). It ranges as a rule between 3 and 6 feet in thickness and occurs from 50 to 70 feet above the Trinidad sandstone. The Peerless mine was abandoned after striking a strong flow of water, which in 1908 was reported to be pumped to the mining camps at Hastings, Delagua, and Berwind.

The Empire mine (No. 86), also on the Peerless bed, was not working in 1908. The following section was measured by O. J. Bowman in 1907:

Section of coal bed in Empire mine.

	Ft.	in.
Shale.		
Coal	3	8
Sandstone		2½
Coal	1	2
Shale.		
Total coal	4	10

The following sections of coal in the lowest group were measured in prospect pits about a mile south of Apishapa River at the localities indicated on the map by Nos. 78 to 81:

Sections of coal beds in prospect pits south of Apishapa River.

No. 78.

	Ft.	in.
Shale.		
Coal, shaly	2	
Coal	1	6
Bone	1	4
Coal		7
Total coal and bone	5	5

No. 79.

	Ft.	in.
Shale.		
Coal, coked	1	6
Shale	2	3
Coal		10
Total coal	2	4

No. 80.

	Ft.	in.
Shale.		
Coal, coked, graphite	2	1
Shale	1	1
Coal		3
Shale		5
Coal		7
Shale.		
Total coal	2	11

No. 81.

	Ft.	in.
Shale.		
Coal	2	
Shale		1½
Coal	3	4
Total coal	5	4

North of the Peerless mine the Peerless bed is reported to have been struck in the Brodhead shaft (No. 95) at a depth of 274 feet. A pocket of coal about 6 feet thick is said to have been worked in this shaft, but further working was stopped, the coal being destroyed by a sill of igneous rock. Other mines in this vicinity are on the middle group of coals described on pages 407–409.

The lower group of coal beds outcrops in the face of the cliffs above the Pierre shale lowlands between Aguilar and the north end of the Trinidad district at the county boundary line, as shown on the map. Coal beds have been opened at several prospects and small mines, where the following sections were measured. Immediately north of Aguilar the lower coal group appears to be poorly developed, as indicated by a measurement in a prospect (No. 88).

Section of coal beds in SE. ¼ sec. 21, T. 30 S., R. 65 W.

	Ft.	in.
Shale.		
Coal	1	3
Shale		10
Coal		8
Total coal	1	11

A short distance farther north, however, the coal-bed measures 3 feet 6 inches in the Jewel mine (No. 89), in the northeast quarter of the same section. In a prospect (No. 90) in the SE. ¼ sec. 16, T. 30 S., R. 65 W., 3 feet 7 inches of coal is exposed.

At the Southwestern mine (No. 91), in the NE. ¼ sec. 16, T. 30 S., R. 65 W., the following section was measured, the principal coal being approximately at the horizon of the Peerless bed:

Section of coal bed at Southwestern mine.

	Ft.	in.
Shale.		
Coal	3	
Shale		3
Coal	1	3
Shale.		
Interval	65	
Shale.		
Coal	1	3
Shale	1	
Sandstone		4
Shale and bony coal	1	3
Sandstone, Trinidad.		

The following section shows the stratigraphy of the lower coal group in the northern part of the Trinidad district:

Sections of coal beds in northern part of Trinidad district.

SE. ¼ sec. 9, T. 30 S., R. 65 W. (No. 92).

	Ft.	in.
Sandstone.		
Shale	10	
Coal	3	10
Sandstone and shale	35	
Coal	2	1
Shale	1	
Coal		11
Sandstone and shale	20	
Coke	1	
Shale and sandstone	3	
Coal		9
Shale	1	1
Coal	1	2
Sandstone and shale	55	
Coal	1	7
Shale	3	
Sandstone, Trinidad.		

SE. ¼ sec. 29, T. 29 S., R. 65 W. (No. 104).

	Ft.	in.
Coal	1	2
Shale	10	
Coal	3	6
Sandstone and shale	40	
Coal	1	4
Shale		1
Coal	2	2
Shale and sandstone	12	
Coal		10
Sandstone and shale	15	
Coal	1	
Shale	5	
Sandstone, Trinidad.		

These sections show that the principal coal bed occurs 125 feet above the Trinidad sandstone in No. 92 and 78 feet above in No. 104.

The Rapson mine (No. 93) of the Rapson Coal Mining Company was connected with the Colorado and Southern Railway by a branch in 1908. The bed mined is reported to be about 100 feet above the Trinidad sandstone. The following section was measured here:

Section of coal bed in Rapson mine, face of entry No. 3 south.

	Ft.	in.
Shale.		
Coal, bony		5
Coal	1	11½
Coal, bony		2
Coal	1	4
Shale.		
Total coal	3	10½

In the Thomas mine (No. 94) of the Wichita Coal and Material Company, connected with the Colorado and Southern Railway by the same branch as the Rapson mine, the following section was measured:

Section of coal bed in Thomas mine.

	Ft.	In.
Shale.		
Coal	2	9
Shale		½
Coal		1
Shale		1½
Coal		7
Shale.		
Total coal	3	5

The Black Diamond mine (No. 103) of the Cedar Hill Coal and Coke Company is situated on the bench above the Trinidad sandstone and is connected with the Colorado and Southern Railway by a short spur. The coal bed is about 80 feet above the Trinidad sandstone. The following section was measured in this mine:

Section of coal bed in Black Diamond mine.

	Ft.	In.
Shale.		
Coal		6
Shale		5
Coal		11
Shale		8
Coal	2	3
Shale.		
Total coal	3	8

MIDDLE COAL GROUP.

Above the lower coal group, which includes a zone of about 250 feet of strata above the top of the Trinidad sandstone, there is a barren zone of 200 to 300 feet of beds in which no workable coal has yet been found, although a few diamond-drill records show the presence of thin coaly layers. In places, as stated on page 387, a varying bed of conglomerate and conglomeratic sandstone lies immediately above the lower coal group. This interval of generally barren strata separates the lower and middle coal groups. The division is useful only for purposes of description and classification, for, as already stated, the entire lower portion of the "Laramie" formation is coal bearing. The middle group of coal beds is confined to about 200 feet of strata which lie between 400 and 600 feet above the top of the Trinidad sandstone. This group is not nearly so persistent as the lower group, and workable beds belonging to the middle group are known at only a few rather widely separated localities. No attempt, however, has been made by prospecting to trace the coal beds of the middle group from one area to another where these coals are being mined.

In the Raton field, adjacent to the New Mexico-Colorado boundary, coal beds occurring in the general stratigraphic position of the middle group of the Trinidad field, according to Willis T. Lee, are well developed and are worked at the Blossburg and Yankee mines and at other places. But in Colorado natural exposures are poor on the wooded talus-covered slopes of Raton Mesa. Nevertheless, from one to four varying beds of coal, lying between 400 and 450 feet above the Trinidad sandstone and ranging from 2 to 4 feet in thickness, are known in this area. At only a single locality, the Fishers Peak mine (No. 8), on the north slope of Raton Mesa, is one of the middle coal beds worked.

The Fishers Peak mine is situated in the NW. ¼ sec. 32, T. 33 S., R. 63 W., about 3 miles southeast of Trinidad, with which it is connected by wagon road. The coal bed is estimated to be 425 feet above the Trinidad sandstone and varies in thickness from 6 inches to 4 feet, as shown by measurements in the mine. The following section was measured in the mine 300 feet from the entrance:

Section of coal bed in Fishers Peak mine.

	Ft.	in.
Shale roof.		
Coal	1	2
Shale		1
Coal		5
Shale		4
Coal		8
Coal and bone	1	4
Shale floor.		
Total coal and bone	3	7

Nothing is known of the middle group of coal beds between the Fishers Peak mine and Apishapa River, except that a few thin beds have been noted in diamond-drill records which the writer is not at liberty to describe. North of Apishapa River, however, as far as the boundary between Las Animas and Huerfano counties, the middle group of coals is locally well developed and mines on these beds are worked by the Las Animas, Green Cañon, Primrose, and Rugby coal companies (Nos. 96–100).

Albert G. Brodhead, who has done much to exploit this region, states that diamond drilling shows the presence of several varying beds of coal between 500 and 600 feet above the Trinidad sandstone. Three beds are reported to average about 4 feet each, although the thickness in places is reduced by partings of shale. Difficulty in mining has been caused by a local flexure that has caused the strata in places to dip steeply, but beyond the flexure the beds have the normal low westward inclination, and in places sills of igneous rock have destroyed the coal. The following sections were measured in the Green Cañon mine:

Sections of coal bed in Green Cañon mine.

	Ft.	in.		Ft.	in.
Sandstone.			Sandstone.		
Coal	2	10	Coal	2	4
Shale		1	Shale		6½
Coal	2	1	Coal	1	8
Shale.					
Total coal	4	11	Total coal	4	

The mines of the Las Animas and Green Cañon companies are reached by a branch line of the Colorado and Southern Railway, which passes through the town of Aguilar and up Gonzales Creek.

The Primrose (No. 99) and Rugby (No. 100) mines, situated at the extreme north end of the Trinidad district, are on the same bed of coal. Two beds about 60 feet apart are present, but the upper bed, which is reported to be about 3 feet thick, is not worked. The lower of the two beds is mined. It averages about 4 feet in thickness and is estimated to be 500 feet above the Trinidad sandstone. In the Primrose mine a parting of shale, said to average 4 inches in thickness, is present about midway in the bed, but in the Rugby mine the parting has not been reported. The following section was measured in the Primrose mine:

Section of coal bed in Primrose mine, room 3, entry 1½ north.

	Ft.	in.
Shale.		
Coal		11
Shale		1
Coal	3	4
Shale.		
Total coal	4	3

The Primrose and Rugby mines are connected by a tramway with a branch of the Colorado and Southern Railway.

These coal beds of the middle group have not been traced south of the Brodhead property or north of the Rugby mine.

UPPER COAL GROUP.

The upper coal group consists of varying coal beds (from one to six beds, usually more than 18 inches thick) that in general lie between 800 and 1,200 feet above the top of the Trinidad sandstone. This group is not in all places clearly separable from the underlying groups, but in general it can be recognized without difficulty. In some sections thin, commercially unimportant layers of coal occur at varying intervals between the middle and upper groups, as was also noted between the middle and lower groups. These sporadic occurrences of thin beds of coal between the major groups emphasize the fact that the lower 1,200 feet or so of the "Laramie" is coal bearing, but it is nevertheless a fact that the known beds of workable thickness fall into one of the three groups here described. The upper group of coals, like the middle group, is not so persistent as the lower group, and workable beds in it are known only in certain areas. The upper group of coals appears to be confined to the Trinidad district and to the southern interior portion of the field. Figure 6 shows the usual topographic and stratigraphic occurrence of the groups.

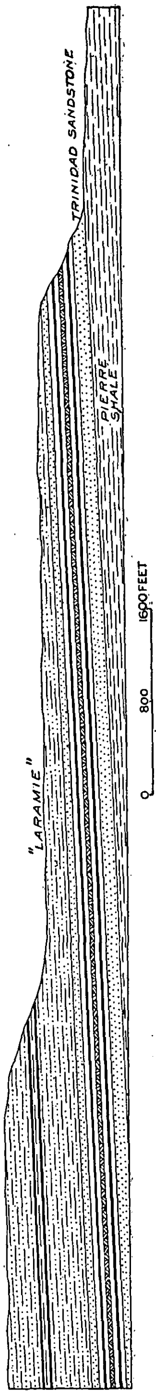


FIGURE 6.—Section of rocks near Delagua and Hastings, Colo., showing upper and lower coal groups.

In the Trinidad district the best-known occurrences of the upper group of coal beds are at Delagua, on Apishapa River above Aguilar, and in Road Canyon. Coal beds have not been traced continuously from one of these areas to another, but there is little doubt that the coal group is continuous, even if no individual bed extends through all three localities. In prospecting to determine the possible connection between Road Canyon and West Canyon in the Purgatory district the boundary line between the areas in which the top of the Trinidad sandstone is greater and less than 1,000 feet beneath the surface (see Pl. XX) may be of assistance, for it marks this approximate horizon.

The Delagua mine (No. 68) of the Victor Fuel Company, in sec. 15, T. 31 S., R. 65 W., is one of the large mines of the Trinidad field. The bed worked is estimated to be 850 feet above the Trinidad sandstone. The thickness of the bed varies from place to place, as well as the number and thickness of the partings of shale. At one place 5 feet 10 inches of clean coal was measured, while a few hundred feet away the bed contained 2 inches of shale 6 inches from the roof and 4 inches of shale 3 feet 3 inches from the roof. The following section was measured in the Delagua mine:

Section of coal bed in Delagua mine.

	Ft.	in.
Shale.		
Coal		8
Shale		6
Coal	2	9
Shale		10
Coal	2	6
Shale.		
Total coal	5	11

The Delagua mine is connected by rail with the Hastings mine and thence with both the Colorado and Southern and the Denver and Rio Grande railroads.

The upper group of coals is worked in a small way at the Bear Canyon mine (No. 65) in the NW. ¼ sec. 11, T. 32 S., R. 65 W., where two beds 30 feet apart are exposed, as shown in the section:

Section of coal beds at Bear Canyon mine.

	Ft.	in.
Shale.		
Coal		11
Shale		6
Coal	1	
Shale		1
Coal	2	4
Interval	30	
Coal	2	
Bone		3
Coal	2	
Total coal	8	3

The Bear Canyon mine has no direct railroad connection, but the property is only about a mile from the end of the branch railroad at the Toller shaft.

As shown on the map (Pl. XX), the upper coal group has been prospected at a number of localities on Apishapa River, where measurements show coal beds between 3 and 5 feet thick. Although a railroad could easily be constructed up the broad river valley, the coal here remains undeveloped.

WALSENBURG DISTRICT.

The Walsenburg district includes the area contiguous to the outcrops of coal beds along the eastern and northern margin of the Trinidad field, north of the boundary line between Las Animas and Huerfano counties. Near the county line the coal outcrops in the face of steep cliffs, but farther north the cliffs are less prominent and the greater part of the Walsenburg district is a relatively low-lying area of little relief. The Trinidad sandstone is generally inconspicuous and the coal-bearing "Laramie" formation is succeeded by the Poison Canyon formation, which at the northwest end of the area overlaps the coal outcrop and conceals the probable extension of the Trinidad coal field in Huerfano Park. Along the eastern margin of the district the strata dip about 3° W., but the dip decreases westward to almost nothing in the center of the basin. At the north end of the field the strike curves around to the west and finally turns southwest, conforming to the general structure of the region, and at the northwest end of the field the dip is about 15° SE. Only the lower group of coal beds is worked in the Walsenburg district. The middle group apparently is not well developed here and the upper group was either never deposited or has been eroded or covered by the overlap of younger deposits.

The lower group in the Walsenburg district consists of two to eight beds more than 18 inches thick within a zone of 250 feet above the top of the Trinidad sandstone. In the vicinity of Walsenburg three workable beds are present, which are known as the Cameron, Walsen, and Robinson beds, but these beds are not persistent and where they have not actually been traced correlation should not be assumed.

In the vicinity of Santa Clara Creek, in the southern part of the Walsenburg district, there are several large mines with railroad connections. At the Santa Clara or new Rouse mine (No. 106) of the Colorado Fuel and Iron Company a bed of coal reported to range from 5 feet to 6 feet 8 inches in thickness is worked. This is said to be the middle one of three workable beds in this area. The following section was measured at the face of the eighth east entry near the end of the main slope:

Section of coal bed in Rouse mine.

	Ft.	in.
Shale.		
Coal	2	6
Sandstone, shaly		4½
Coal	3	3½
Shale.		
Total coal	5	9½

At the Midway mine (No. 107) of the Chicosa Fuel Company and the Pryor mines (Nos. 108–110) of the Union Coal and Coke Company three beds of coal are worked. These are locally known as the Cameron (lowest), Walsen (middle), and Robinson (upper) beds, the names of coals in the vicinity of Walsenburg being used, but the beds have not been traced between these places, and it is by no means certain that they are continuous. The following measurements were made at the Pryor mines:

Section of coal beds at the Pryor mines.

		Ft.	in.
Sandstone, irregular streak of "draw slate"			1–3
Coal	upper bed	1	8
Parting	upper bed		6
Coal	upper bed	3	3
Parting	upper bed		4
Coal	upper bed	1	2
Interval		35±	
Shale.			
Coal	middle bed	2	4
Coal, bony	middle bed		4–10
Sandstone	middle bed		2
Coal	middle bed	3	4
Shale.			
Interval		30±	
Coal, lower bed		4	6
Total coal		16 to 17	7 / 1

The lowest coal bed lies practically on or within a few feet above the Trinidad sandstone.

A zone of normal faults is present in the vicinity of these mines, the downthrow being on the west. At the Rouse mine the displacement is the greatest reported—85 feet. At the Midway mine the throw is not so great, but is enough to cause a peculiar condition. The slope

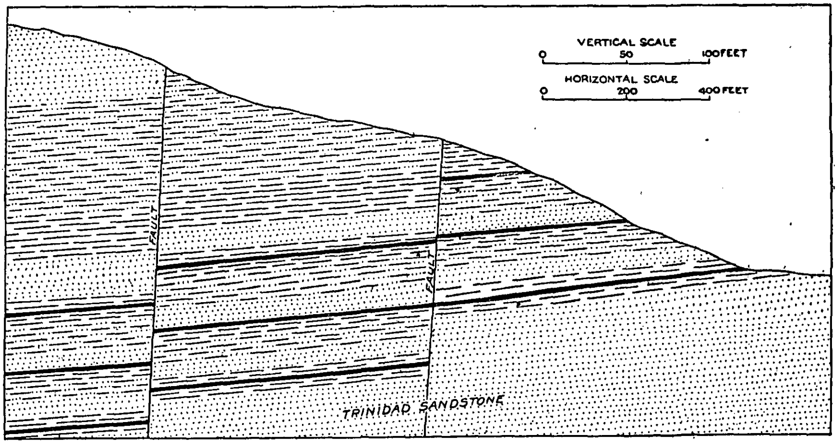


FIGURE 7.—Faulted coal beds in Midway mine, Trinidad coal field, Colorado.

enters on the lowest bed, but at a distance of about 800 feet a fault is encountered with just sufficient throw, 32 feet, to bring the overlying middle coal bed abreast of the lowest coal bed, as shown in figure 7. Figure 8 illustrates a small fault in the Berwind mine.

The Hezron (No. 111) and old Rouse (No. 115) mines of the Colorado Fuel and Iron Company were formerly large producers with

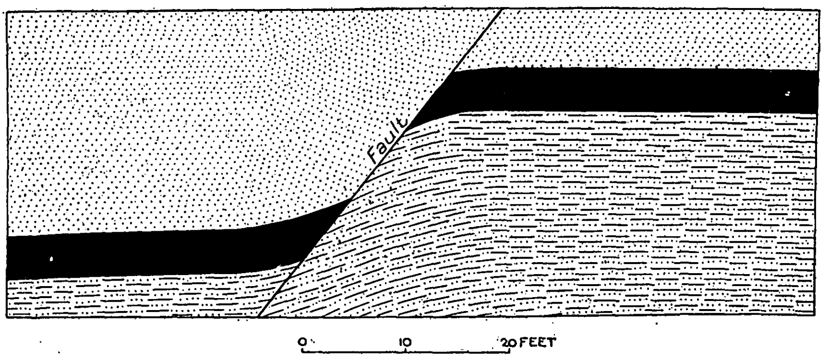


FIGURE 8.—Fault in Berwind mine, Trinidad coal field, Colorado.

railroad connection, but neither mine was worked in 1908. The coal bed in the Hezron mine, reported to be 5 feet thick but to contain a number of varying partings, is about 170 feet above the Trinidad sandstone. R. C. Hills states that at the old Rouse mine the lowest bed has a thickness of 6½ to 7 feet.

At a prospect in sec. 35, T. 28 S., R. 66 W. (No. 116), the coal is 4 feet thick, and at another, in sec. 34, T. 28 S., R. 66 W. (No. 117), it is 2 feet 3 inches thick. The roof and floor are shale at both these prospects, which lie northwest of the old Rouse mine.

The Round Oak (No. 118), in sec. 27, T. 28 S., R. 68 W., a small mine without railroad connection, is, so far as the writer is aware, on the thinnest bed of coal that is being mined in the Trinidad field, a measurement showing only 2 feet 5 inches of coal. It is well known, however, that in many localities beds of coal only 18 inches thick are profitably worked. An upper bed of coal on the Round Oak property measures 4 feet 5 inches.

The three workable coal beds in the vicinity of Walsenburg are shown in the following section:

General section of coal beds near Walsenburg.

	Feet.
Coal, Robinson bed	6–7
Interval	60
Coal, Walsen bed	6
Interval	35
Coal, Cameron bed	2–4
Shale	5
Sandstone, Trinidad.	

In the Ravenwood mine (No. 120), in the SE. ¼ sec. 21, T. 28 S., R. 66 W., on the Cameron bed, the following section was measured:

Section of coal bed in Ravenwood mine.

	Ft.	in.
Shale.		
Coal	2	8
Parting, thin.		
Coal		6
Shale.		
Total coal	3	2

At the new Cameron mine (No. 122), 1 mile south of Walsenburg, the Colorado Fuel and Iron Company has recently opened a mine on the Cameron bed. At the entrance to the workings 3 feet 7 inches of coal, with 2 feet of shale lying between it and the Trinidad sandstone, is exposed, but about 1,500 feet down the slope the bed has a thickness of only 2 feet.

In the valley of Cuchara River immediately west of Walsenburg mines from which the coals are named have been worked for many years on all three beds. Measurements could not be made in the old Cameron mine, but the following was made in the Walsen mine:

Section of coal bed in Walsen mine (No. 123).

	Ft.	in.
Shale.		
Coal		9
Coal, bony		8
Coal	2	9½
Clay		2½
Coal	1	6
Shale.		
Total coal	5	8½

In the Robinson mine (No. 125), in the eighth cross entry off the eighth north entry, there is 7 feet of coal with shale roof and floor.

The Huerfano mine (No. 126), in the NW. ¼ sec. 8, T. 28 S., R. 66 W., reaches the coal by means of a shaft 50 feet deep.

A great dike extending across the country for many miles[a] cuts across the outcrop of coal about a mile northwest of Walsenburg, and different names have been given to the three workable coal beds north of the dike. The lowest bed is there known as the Maitland, the middle bed as the Lennox, and the upper as the Monarch. Drill records and the experience of operators in this vicinity, however, show that the three beds are not persistent and that it is a mistake to apply these names to beds at any considerable distance from the vicinity of the type localities, the Pictou and Maitland mines, unless their identity has been established.

It is reported that at the Toltec mine (No. 128) of the Northern Coal and Coke Company the upper and middle beds are worked. At the Pictou mine (No. 129) of the Colorado Fuel and Iron Company all three beds are worked, but about 2,500 feet in from the mouth of the slope on the upper bed the upper and middle coalesce into a single bed 10 feet thick. At the entrance to the mine the upper and middle beds are 30 feet apart and the middle and lower beds 15 feet apart; and at the junction of the upper and middle the united bed is 20 feet above the lower. (See fig. 9.)

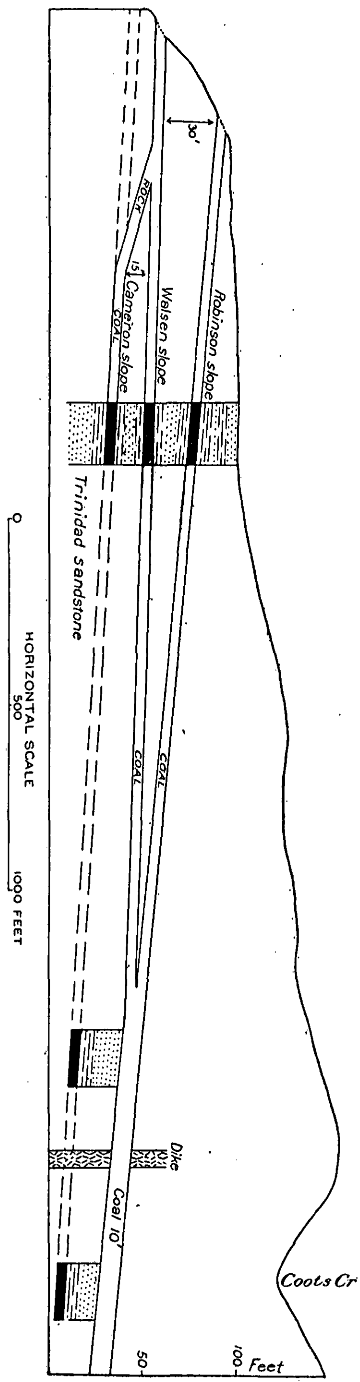


FIGURE 9.—Section in Pictou mine, Pictou, Colo., showing coalescence of beds. By J. S. Thompson, superintendent.

[a] Walsenburg folio (No. 68), Geol. Atlas U.S., U.S. Geol. Survey, 1900.

The Maitland mine (Nos. 132–133) of the Victor Fuel Company, in sec. 31, T. 27 S., R. 66 W., is on the lower two beds, the Maitland and Lennox, which are separated by an interval of 10 to 30 feet, the Maitland bed lying practically on the Trinidad sandstone. The Maitland bed is reported to range between 4 feet 6 inches and 6 feet in thickness, with a varying parting up to 5 inches thick. The Lennox bed is from 3 to 4 feet thick, with but little bone. The workings of the Maitland and Pictou mines are connected by means of the Champion and Sunshine mines, which are much smaller producers.

North of the Maitland mine there are a few small workings, but the next large mine is the Piñon (No. 136) of the Rocky Mountain Fuel Company, in sec. 23, T. 27 S., R. 67 W. Two beds about 140 feet apart are worked in this mine. The upper bed, which is worked from a slope, is reported to run from 6 to 7 feet in thickness, with a parting from 4 to 18 inches thick in the middle of the bed. This slope was not in operation when visited in 1908. The lower bed, which lies practically on the Trinidad sandstone, is entered from a shaft 120 feet deep. The following section was measured here:

Section of lowest coal bed at Piñon mine.

	Ft.	in.
Shale.		
Coal, bony		10
Coal	4	2
Shale.		
Total coal and bone	5	

This shaft and those at the Huerfano and Toller mines are the only shafts at present being operated in the Trinidad field.

At the extreme north end of the field several mines have recently been opened which, like all the mines north of Walsenburg, have railroad connection by a branch of the Denver and Rio Grande, extending northwest to Walsenburg along the outcrop of the principal coal beds.

At the Laramie mine (No. 139), in the NE. ¼ sec. 9, T. 27 S., R. 67 W., the following section was measured:

Section of coal bed in the Laramie mine.

	Ft.	in.
Shale.		
Coal	5	6
Shale		1
Coal		10
Total coal	6	4

At Strong the Sunnyside mine (No. 140) of the Sunnyside Coal Mining Company is on a bed which lies within a few feet of the Trinidad sandstone. The following section was measured in the mine.

Section of coal bed at face of main slope in the Sunnyside mine.

	Ft.	In.
Sandstone.		
Shale		8
Coal	5	5
Bone		1
Coal	1	8
Shale.		
Total coal	7	1

An irregular shale parting is said to be of common occurrence within 18 inches of the roof.

It is reported that a mile southwest of Strong, at the Tioga mine (No. 142) of the Minnequa Coal Company the 7-foot lower bed worked at the Sunnyside mine has a thickness of only 4 feet and the upper bed, which at Strong is the thinner, is 6 feet thick and is the better of the two. A slope on the lower bed at Tioga has been abandoned, and one on the upper bed, which is about 50 feet above the lower, is being opened. The coal here dips 15° S. 45° E.

Southwest of the Tioga mine the surface is occupied by silt and the coal must be prospected by drilling.

At the Big Four mine (No. 143), opened in 1908, two beds of coal have been found, 48 feet apart. The upper bed, as at the Tioga mine, is being worked, but the lower bed is reported to be dirty and variant. In this mine 6 feet 10 inches of coal was measured. The dip of the beds is 12° S. 60° E.

Practically nothing is known of the coal between the Big Four mine and the Oakdale mine on the opposite side of the basin (p. 419). In this area the coal-bearing rocks are covered by an overlap of Tertiary and Quaternary deposits, and northwest of La Veta igneous rocks forming Veta and Dike mountains interrupt the continuity of the coal field. From the general structure of the region it seems probable that the coal measures extend northwestward in the synclinal area of Huerfano Park where the "Laramie" formation is covered by Eocene and later strata. Although the occurrence of coal in this area must be determined by the drill, it is an inviting field for exploitation.

WESTERN OUTCROP.

LA VETA DISTRICT.

The La Veta district includes the area contiguous to the coal outcrop along the northwestern margin of the Trinidad coal field from its farthest known extent on the flanks of Veta Mountain southward to the vicinity of the Huerfano-Las Animas county boundary line, where the coal outcrop is interrupted by a mass of intrusive igneous rock.

In this area the coal-bearing rocks in general dip northeastward at angles ranging from 10° to 65°, but at the northwest end of the district there is a zone in which the rocks are folded in an unsymmetrical anticline and syncline. Here, as throughout the western margin of the Trinidad field, the steep dip causes the coal to outcrop in a comparatively straight line that is in strong contrast to the intricate outcrop along the eastern border of the field, where the dip is low. (See Pl. XX.) The Pierre shale occurs in a narrow strip west of the outcrop of the Trinidad sandstone, which is rather inconspicuous, and broadens out in the axis of the anticline northwest of La Veta. The "Laramie" formation occupies a somewhat wider belt and is unconformably overlain by the Poison Canyon formation.

The coal has not been thoroughly prospected in the La Veta district, although a number of openings have been made along the outcrop, as shown on Plate XX, and a few mines have been opened. Only the lower group of coal beds has been found in this district.

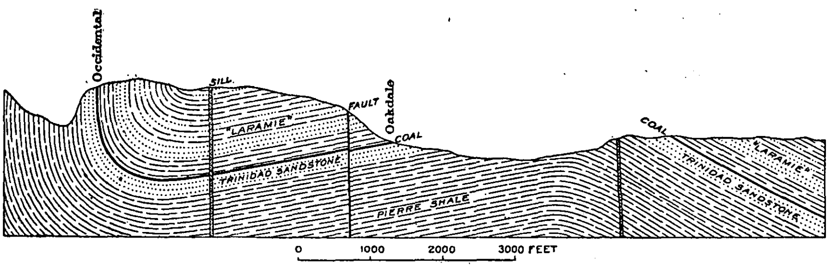


FIGURE 10.—Section between Occidental and Oakdale mines, northwest of La Veta, Colo.

The best-developed part of the La Veta district is in the subsidiary basin north of the Denver and Rio Grande Railroad, 7 miles northwest of La Veta. This is an unsymmetrical syncline about 3 miles long from northwest to southeast and a mile wide. The coal is cut off at the north end of the fold by the intrusion of the mass of igneous rock which forms Veta Mountain. On the western limb of the syncline the coal beds are almost perpendicular and in places are slightly overturned, but generally the dip is steep to the northeast. On the eastern limb the coal dips 15° SW. (See fig. 10.)

The Occidental mine (No. 146) of the Occidental United Metal and Coal Company, in sec. 9, T. 29 S., R. 69 W., when visited in 1908 was not in operation. The mine is connected with the Denver and Rio Grande Railroad by a long, winding tramway. The coal is reached by a tunnel about 300 feet long, which was begun in Pierre shale and was cut through the Trinidad sandstone, here almost perpendicular. Two beds of coal are present, about 45 feet apart. The lower bed, lying within 30 feet of the Trinidad sandstone, is reported to range from 6 to 8 feet in thickness and the upper bed from 3 to 4 feet. (See fig. 11.)

The Oakdale mine (No. 149) of the Oakdale Coal Company, located on the eastern limb of the detached basin in the SW. ¼ sec. 10, T. 29 S., R. 69 W., has recently been opened and in 1908 was the only shipping mine in the La Veta district. The bed worked lies about 30 feet above the Trinidad sandstone and averages possibly 7 feet 6 inches in thickness. At the foot of the slope 7 feet 4 inches of clean coal was measured. In the mine the coal is cut by a fault having a downthrow on the east of 22 feet. A number of prospects have been opened on the coal in the detached syncline, as shown on the map (Pl. XX), but there are as yet no other working mines there.

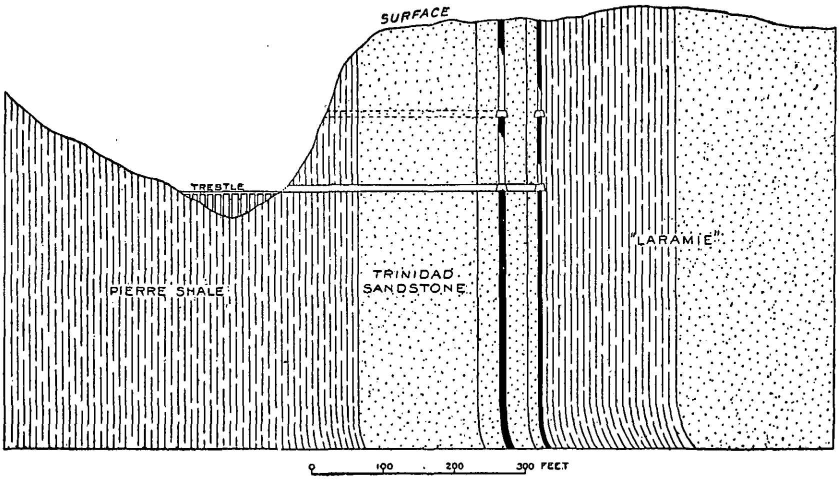


FIGURE 11.—Section at Occidental mine, west of La Veta, Colo.

The coal outcrop along the main western margin of the Spanish Peaks syncline west of La Veta has been prospected in a number of places and a few small mines have been opened, but railroad connection has not yet been extended to them. The following measurements show the thickness of the coal beds where they have been exposed:

Sections of coal beds west of La Veta.

NW. ¼ sec. 14, T. 29 S., R. 69 W. (No. 152).

	Ft.	in.
Sandstone.		
Coal		4
Sandstone		½
Coal	2	5
Sandstone.		
Total coal	2	9

SE. ¼ sec. 15, T. 29 S., R. 69 W. (No. 153).

	Feet.
Sandstone.	
Coal	3
Shale.	

SE. ¼ sec. 22, T. 29 S., R. 69 W. (No. 154).

	Ft.	in.
Shale.		
Coal	2	6
Shale	2	10
Coal	2	2
Total coal	4	8

Indian Creek mine, NW. ¼ sec. 2, T. 30 S., R. 69 W. (No. 155).

	Ft.	in.
Sandstone.		
Coal	1	8
Sandstone	4	
Coal	2	8
Total coal	4	4

NE. ¼ sec. 11, T. 30 S., R. 69 W. (No. 156).

	Ft.	in.
Shale.		
Coal	3	
Shale		6
Coal	3	
Total coal	6	

Springer tunnel, SE. ¼ sec. 11, T. 30 S., R. 69 W. (No. 157).

	Ft.	in.
Coal	1	6
Sandstone		1
Coal	1	4
Total coal	2	10

STONEWALL DISTRICT.

The Stonewall district includes the area contiguous to the coal outcrop along the western margin of the coal field from the vicinity of the Huerfano-Las Animas county boundary line, where the coal outcrop is interrupted by a mass of intrusive igneous rock, southward for a distance of about 17 miles to the entrance to the Tercio embayment, on South Fork of Purgatory River. In this area the coal-bearing rocks dip eastward at angles ranging from 25° to 70°.

The Pierre shale occupies a narrow lowland zone west of the "Laramie" formation and is cut by several dikes of igneous rock which strike parallel to the strata and stand out in prominent relief in the midst of the shale lowland. West of the Pierre shale the Dakota sandstone, dipping about 80° E. and being overlain by relatively soft beds, stands out as a conspicuous wall that is called the Stonewall and is a well-known local landmark. In the northern part of the Stonewall district, where the surface altitude is higher, Eocene beds, marked by a well-developed basal conglomerate, outcrop, but farther south these rocks have been eroded and the "Laramie" formation occupies the surface.

The lower group of coal beds has been prospected to some extent in the Stonewall district, but on account of the absence of railroads no mines have been opened. Little is known of the upper coal beds, except in the valley of Middle Fork of Purgatory River west of Vigil, where along the roadside a coal bed is exposed which probably lies about 1,000 feet above the Trinidad sandstone. Nothing is yet known of the middle group of coal beds in the Stonewall district.

The following measurements, beginning at the north and proceeding southward, show the thickness of the coal where it has been prospected in the Stonewall district.

Sections of coal beds in Stonewall district.

SW. ¼ sec. 25, T. 31 S., R. 69 W. (No. 48).

	Ft.	in.
Shale.		
Coal		2
Shale	1	9
Coal		3
Shale	1	6
Coal	3	4
Sandstone		1
Coal	2	3
Shale.		
Total coal	6	

SW. ¼ sec. 6, T. 32 S., R. 68 W. (No. 47).

	Ft.	in.
Shale.		
Coal	1	
Shale		2
Coal	3	11
Sandstone		1
Coal	1	10
Shale.		
Total coal	6	9

SW. ¼ sec. 6, T. 32 S., R. 68 W. (No. 46).

	Ft.	in.
Shale.		
Coal, shaly	1	4
Shale		1½
Coal	3	8
Sandstone		¾
Coal	1	8
Total coal	6	8

NE. ¼ sec. 18, T. 32 S., R. 68 W. (No. 45).

	Feet.
Shale.	
Coal	6
Shale.	

NW. ¼ sec. 20, T. 32 S., R. 68 W. (No. 44).

	Ft.	in.
Coke	5+	
Impure coke	1	6
Shale.		

SE. ¼ sec. 20, T. 32 S., R. 68 W. (No. 43).

	Ft.	in.
Shale.		
Coal	1	5
Shale		3½
Coal	1	4
Shale		1½
Coal	3	4+
Total coal	6	1+

NE. ¼ sec. 29, T. 32 S., R. 68 W. (No. 42).

	Ft.	in.
Coal	8	8+

SW. ¼ sec. 33, T. 32 S., R. 68 W. (No. 41).

	Ft.	in.
Shale.		
Coal, bony		7
Shale		8
Coal	6	6
Total coal	7	1

NW. ¼ sec. 4, T. 33 S., R. 68 W. (No. 40).

	Ft.	in.
Shale.		
Coal	2	8
Interval	150	
Coal	5	6
Shale.		
Total coal	8	2

Maxwell grant, three-fourths mile south of North Fork of Purgatory River (No. 39).

	Ft.	in.
Coal	1	
Shale	10	
Coal	1	
Shale	3	
Sandstone	5	
Coal	3	6
Shale.		
Total coal	5	6

West of Stonewall post-office, one-half mile north of Middle Fork of Purgatory River (No. 38).

	Ft.	in.
Shale.		
Coal	2	
Shale		4
Coal	2	2+
Interval	150	
Shale.		
Coal	3	
Clay		2
Coal		10
Clay		2
Coal	1	1
Interval	45	
Trinidad sandstone.		
Total coal	9	1

One-half mile south of Middle Fork of Purgatory River (No. 37).

	Ft.	in.
Sandstone.		
Coal	7	8
Shale.		

Two miles south of Middle Fork of Purgatory River (No. 36).

	Ft.	in.
Shale.		
Coal	3	6
Shale.		

TERCIO DISTRICT.

The Tercio district includes the area contiguous to the coal outcrop in the Tercio embayment and southwest of it to the Colorado-New Mexico boundary. The embayment is an anticlinal area from which erosion has worn away the "Laramie" formation in the central part and exposed the Pierre shale in a broad park-like valley. (See fig. 12.)

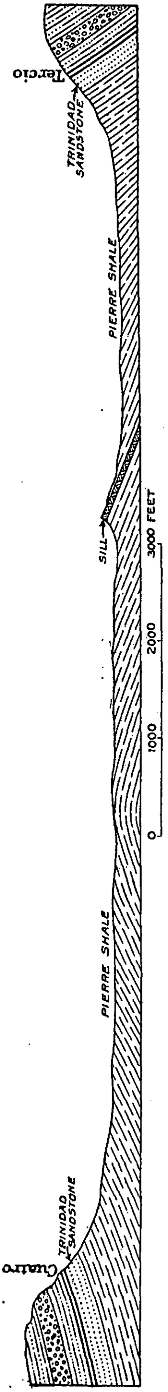


FIGURE 12.—Section between Cuatro and Tercio, Colo.

In this district the strata on the southwestern flanks of the Spanish Peaks syncline have been warped into a subordinate anticline and syncline which extend southward across the state boundary into the Raton coal field. The syncline west of the Tercio embayment has a southward-plunging north-south axis. On the west limb of this fold the strata dip about 25° SE. and on the east limb the dip is about 15° SW. The axis of the Tercio anticline strikes northwest and southeast and the fold is unsymmetrical, the dips being about 55° on the northeast limb and 15° on the southwest limb. Not far northeast of Tercio the dips flatten, and throughout the greater part of the distance between Tercio and Weston the strata lie almost flat, with a northeastward inclination of only a few degrees.

The Pierre shale occupies the surface of the Tercio embayment and to the southwest outcrops in a narrow zone along the base of the western limb of the syncline. Lying immediately above this shale, the Trinidad sandstone forms a locally prominent escarpment above which the coal-bearing rocks outcrop. A bed of conglomeratic sandstone and conglomerate, about 150 feet thick, composed of rounded pebbles of quartz up to 1 inch in diameter, is conspicuously exposed around the rim of the Tercio embayment and occurs about 200 feet above the Trinidad sandstone. This conglomerate in the size and composition of its constituents is in marked contrast to the conglomerate at the base of the Poison Canyon formation 15 miles to the north.

The lower group of coal beds, consisting of two to four beds more than 2 feet thick, occurs between the Trinidad sandstone and the conglomerate and has been considerably exploited throughout the district. These are the only coals that have been prospected, although a bed in the upper group, probably in the same zone as that at Weston (p. 427), is locally exposed.

The Colorado Fuel and Iron Company has expended considerable money in developing the Tercio district, but thus far with poor results. The Colorado and Wyoming Railroad was built up Purgatory Valley to Tercio, where a model mining camp has been constructed; but when visited in 1908 this plant was shut down and, except for some prospecting at Cornell (No. 35), practically no work was being done in the Tercio district.

The following sections show the thickness and stratigraphic occurrence of the coal in this district:

Sections in Tercio district.

Cuatro (No. 34).

	Ft.	In.
Shale.		
Coal	2	8
Shale	4	
Coal	2	
Shale	15	
Coal	3	7
Shale	7	
Sandstone	18	
Shale	27	
Coal	4	5
Shale	2-10	
Sandstone, Trinidad.		
Total coal	12	8

Cornell (No. 35).

	Ft.	In.
Sandstone, conglomeratic.		
Interval	175	
Coal	2	
Bone		7
Coal	2	6
Shale		3
Coal	1	1
Shale	11	
Coal	3	
Shale	4	
Coal	1	
Sandstone, Trinidad.		
Total coal	9	7

At the Tercio mine (No. 33) two beds were mined in which the following measurements were made by J. W. Groves in 1907:

Section of coal beds in Tercio mine.

	Ft.	In.
Shale.		
Coal	1	2
Bone		2
Coal	2	1
Shale.		
Interval.		
Shale.		
Coal	1	
Bone		2½
Coal	2	
Bone		3
Coal	2	8
Shale		1
Coal		10
Shale.		
Total coal	9	9

INTERIOR DISTRICTS.

MORLEY DISTRICT.

The Morley district includes the area contiguous to the coal outcrops in the vicinity of Morley and Wootton, stations on the Santa Fe Railway, in the southern part of the coal field. In the vicinity of Morley a local fold has brought to the surface the lower coal group, as well as the underlying Trinidad sandstone and Pierre shale. The fold has the form of a narrow elongated dome, from the center of which the beds dip on all sides at an average angle of about 10°. The longer axis of the fold strikes northwest and southeast, and it is probable that the fold is terminated on the north, about two miles from Morley, by a fault striking somewhat north of west, with an upthrow on the south of about 600 feet. The presence of a fault here was suggested by a section made up North Raton Creek between Starkville and Morley, but its existence has not been proved.

The assignment of the Morley coal bed to the lower coal group differs from Hills's conclusions in the Spanish Peaks folio, but there can be no doubt regarding the fact that the coal bed is immediately underlain by typical Trinidad sandstone containing *Halymenites*, and that this in turn is underlain by Pierre shale in which *Inoceramus* occurs. It should be noted that the miners correctly consider the Morley bed to belong to the same group as the Starkville-Engle coal, and also that Stevenson[a] in 1878 announced its correct position.

The coal bed at Morley lies almost on the massive member of the Trinidad sandstone, one measurement showing 2 feet of shale and 10 feet of thin-bedded sandstone and shale between the coal and the main mass of the sandstone. A fine bed of coal is being developed at the new mine at Morley, which apparently is destined to be one of the prominent mines of the field. The bed is reported to average 7 feet of clean coal, though in places it thickens to 8 feet 8 inches, with 4 inches of bone 2 feet below the top.

Other coal beds have not yet been developed in this vicinity and little is known of their occurrence, but at Wootton the upper coal group is exposed, consisting of several varying coal beds ranging from 6 inches to 5 feet in thickness, occurring within a zone of about 100 feet of strata. A number of prospects have been opened on these beds and a new mine, the Red Robin, was being developed in 1908. In the absence of deep drilling and because of the complexity caused by the Morley dome it is difficult to determine in the Trinidad field the exact stratigraphic position of the Wootton coal beds, but sections measured across Raton Pass and correlated with Lee's work in the Raton coal field show that the topmost coal at Wootton is approximately 850 feet above the Trinidad sandstone.

[a] Stevenson, J. J., U. S. Geog. Surveys W. 100th Mer., vol. 3, Supplement, 1878.

The following section was measured in the Red Robin mine (No. 1) of the Wootton Land and Fuel Company at Wootton:

Section of coal bed in the Red Robin mine.

	Ft.	In.
Shale.		
Coal	3	1
Bone		½
Coal	1	5
Bone		1½
Coal		4
Shale.		
Total coal	4	10

Between 150 and 200 feet above the Wootton coal beds another but much less important set of beds, known as the Tunnel coals, is exposed at the north entrance to the Santa Fe tunnel at Raton Pass, immediately south of the Colorado-New Mexico boundary line. At this place six beds of coal, varying from 1 foot down to a few inches, occur interbedded with sandstone and shale within a zone of 10 feet. On the hillsides above the Wootton coals there are two or three beds belonging to the Tunnel group, ranging from 8 to 20 inches in thickness.

PURGATORY DISTRICT.

The Purgatory district includes the area contiguous to the outcrops of the upper and middle groups of coal beds in the valley of Purgatory River. As now developed, mines have been opened at Primero, Sexto, Frederick, and Quinto. The following section, measured in Purgatory Valley between Sopris and Weston, shows the general sequence of the strata:

Section of rocks in Purgatory Valley between Weston and Sopris.

	Feet.
Coal, Weston.	
Shale, dark	10
Sandstone, gray, massive	50
Sill zone, dark shale, and alternating sills of igneous rock	40
Sandstone, gray, massive, first above camp at Doran's ranch	20
Shale, drab	30
Sandstone, gray, massive	10
Shale, poor coal at top	30
Sandstone, brown, massive	20
Shale and sandstone	50
Coal, Frederick.	
Shale, some thin sandstones	33
Sandstone, gray, massive	25
Shale, some thin sandstones	40
Sandstones, thin bedded, brown, with thin alternating shale	143
Sandstone, very light colored, massive, soft	9
Sill of igneous rock	1
Shale, drab	15
Sandstone, brown, massive	5
Shale, drab	16
Sill of igneous rock	2
Shale, drab	10

	Feet.
Sandstone, brown, massive	4
Shale, dark, with irregular sandy layers	53
Sandstone, gray, massive, false bedded	34
Shale	3
Coal, Sopris.	
	653

The Purgatory district lies in the central part of the syncline, where the strata in general are almost flat. There are local disturbances, however, and the detailed structure is not yet determined. Close correlation of the coal beds also remains to be accomplished; this can best be done by means of a number of diamond-drill holes reaching to the Trinidad sandstone. The section measured along Purgatory River, given above, indicates that the coal bed mined at Frederick is about 400 feet above the Sopris coal, or 590± feet above the Trinidad sandstone.

The variation of the coal is illustrated by the Frederick bed, which was traced from the Frederick mine (No. 24), where it measures 6 feet 6 inches, about 1½ miles southeastward to a point where the bed consists of only 1 foot of bone and coal and from which it could not be further traced. Difficulty was likewise encountered in attempting to trace the bed mined at Primero. At this mine the altitude of the coal is about 350 feet above that at Frederick, but the stratigraphic relation of these two beds has not been determined.

The Primero is well known as one of the largest mines in the Trinidad field. The Frederick mine was but recently (1908) opened, and at Sexto development has not gone beyond the prospecting stage. These properties belong to the Colorado Fuel and Iron Company.

The following measurements show the thickness of these coal beds at the given localities:

Sections of coal beds in the Purgatory district.

Frederick mine (No. 24).

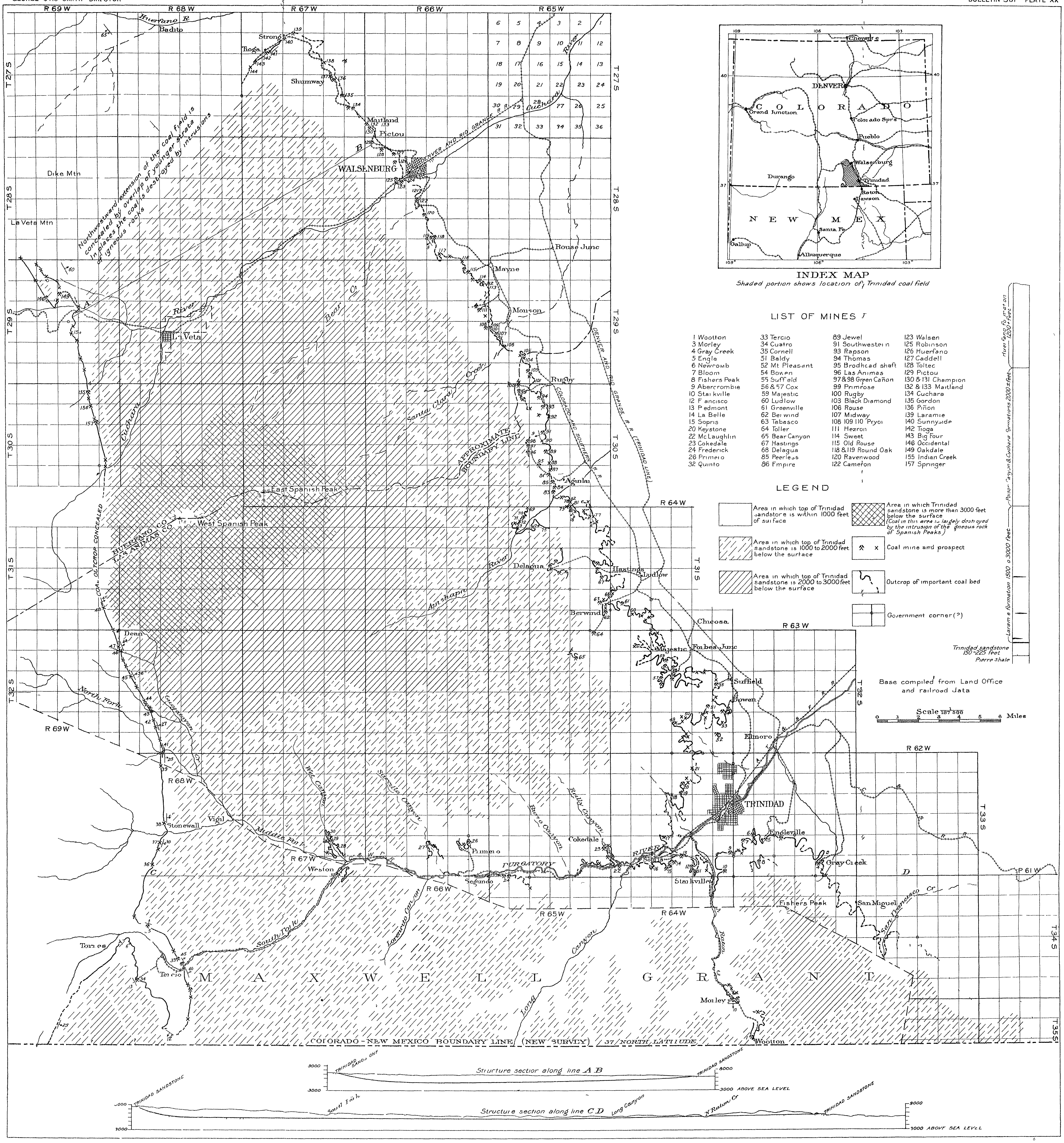
	Ft.	in.
Shale.		
Coal	3	4
Shale		10
Coal	1	11
Shale		5
Coal	1	3
Total coal	6	6

Primero mine (No. 26), room 1, entry A-9.

	Ft.	in.
Shale.		
Coal	1	1
"Sulphur," local		½
Coal	1	4½
Coal, bony		7
Coal		3
"Sulphur," local		1
Coal		4½
"Sulphur"		½
Coal	2	7½
"Sulphur"		1
Coal	1	11
Shale.		
Total coal	8	2½

Sexto (No. 27).

	Ft.	in.
Shale, coaly		5
Coal	1	8
Shale, coaly		7
Coal		6
Shale, coaly		2
Coal	1	6
Shale, floor.		
Total coal	3	8



MAP OF TRINIDAD COAL FIELD, COLORADO

By G B Richardson, D E Winchester, and J H Gardner

House Doc No 1536 60th Cong, 2d Sess

The coal bed in the Primero mine is reported to vary considerably in thickness, and in places it is cut by dikes and sills which have converted the bed into coke. Good examples of prismatic natural coke are exposed here.

The Quinto mine (No. 32) of the Colorado Fuel and Iron Company, situated half a mile south of Weston, was not in operation in 1908. This mine is on a bed in the upper group which is estimated to be about 900 feet above the Trinidad sandstone. A number of prospect pits have been opened in Wet Canyon at approximately the same horizon. The coal bed in this vicinity ranges from 2 to 6 feet in thickness and contains usually one or two shale partings from a few inches to 2 feet thick. The following section was measured in Wet Canyon a mile and a half north of Weston:

Section of coal bed in Wet Canyon (No. 31.).

	Ft.	In.
Sandstone.		
Shale	1	6
Coal	3	8
Shale		2
Coal	1	6
Sandstone.		
Total coal	5	2

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

The coal from all parts of the Trinidad field is of a rich black color, with shiny luster and cubical fracture, indicating a good bituminous grade. Corresponding with the differences in chemical composition, however, there are differences in the physical properties of the coal in various parts of the field. In general, coal from the southern part is distinctly different from that in the northern part, though the change from south to north is gradual.

The most important distinction between the coals from the southern and northern parts of the field is that the former makes an excellent coke, whereas, although several attempts have been made, coke of commercial value has not been produced from coal from the northern part of the field. Until lately no physical criterion has been in general use by which a noncoking coal could be distinguished from a coking variety short of an actual test in a beehive oven. But the recent observation of M. A. Pishel,[a] that when ground to a powder coking coals show a pronounced adhesive quality, whereas noncoking coals do not, holds good for the samples from nearly forty mines in the Trinidad field that have been examined. Tests show that specimens of the high-grade coking coal from the southern part of the field adhere distinctly to the pestle when ground in a mortar. The adhesiveness decreases in samples obtained farther north and coals from

[a] A practical test for coking coal: Econ. Geology, June-July, 1908, pp. 265-270.

the north end of the field show practically none under similar conditions. The cause of this "gummy" quality remains to be determined, but the property appears to be an accompaniment of a coking coal.

Coal from the southern part of the field is typically of a deep black color and a brilliant luster and has well-developed cubical fractures. The major system of joints by which the coal is traversed trends at right angles to the strike of the beds and parting planes are especially well developed at intervals of 1 to 4 inches. Less perfect planes of fracture are usually developed at right angles to the major set, so that when mined the coal tends to come out in blocks. So well are these fractures developed in certain areas, as at the Engle and Starkville mines, that powder is not used in mining, picking being sufficient to get out the coal. In the southern part of the field planes of fracture parallel to the bedding of the coal are not so well developed as in the other two directions, and where the coal is broken along the bedding planes it shows numerous small conchoidal fractures with pitted surfaces having a brilliant luster. A brilliant luster is also developed along the principal fracture planes. The coals are further characterized by the development of minute irregular bands of alternating bright and dull coal parallel to the bedding, which otherwise, except by the presence of partings of bone, sandstone, or shale, is ill defined. There are local exceptions to these general characteristics of the coal. At the Primero mine, for example, the usually pronounced joint planes are poorly developed.

Where the coal has come into contact with igneous rocks marked metamorphism has occurred and the coal has been converted to natural coke. The natural coke from the Trinidad field varies with the composition of the coal and with the size and proximity of the intrusive rock. (See p. 435.) In general the coke is deep black and nonlustrous and has a hardness and specific gravity notably greater than unaltered coal. The most pronounced characteristics of the coke are its tendency toward columnar structure and the devolatilization it has undergone as shown by the chemical analyses. (See p. 435.) Polygonal prisms up to 3 inches in diameter are developed with the longer axes at right angles to the intrusive rock. Thus the prisms associated with sills cross the bedding and the prisms caused by dikes are approximately parallel to the bedding planes. In the Trinidad field natural coke is generally considered worthless and doubtless much of it is so, but coke in which ash is not excessive should make a good fuel. Natural coke from the Richmond Basin, Virginia, has been much used.

The typical coal of the northern part of the field is characterized by a less brilliant luster and less well developed joint planes than that in the southern part. At the north the bedding of the coal is more conspicuous and the bands of alternate bright and dull coal are larger and better developed. There is, however, usually one pronounced set of joint planes. Disseminated patches of rosin also occur in the coal of the northern part of the field.

The presence of "niggerheads" is of rather common occurrence in the northern area. These are nodule-like bodies of coal, varying from a few inches to a few feet in diameter, irregularly disseminated in the beds of normal coal. The "niggerheads" are harder than ordinary coal and have a smooth, locally slickensided, lustrous outer surface. The interior is composed of alternating bands of bright and dull coal like the surrounding bed. "Niggerheads" evidently are due to physical strains, but their origin is obscure.

CHEMICAL COMPOSITION.

The analyses given in the table on pages 138–140 show the composition of 25 representative coal samples from different parts of the Trinidad field. Most of the analyses were made from mine samples of fresh, unweathered coal collected by O. J. Bowman and analyzed at the fuel-testing plant of the United States Geological Survey at Pittsburg under the direction of F. M. Stanton.[a] Eight of the analyses indicated on pages 430–432 were made on car samples representing run-of-mine coal taken by John W. Groves[b] and analyzed at the fuel-testing plant of the Geological Survey at Denver. Ultimate and proximate analyses were made of each sample, and the results are expressed in four forms, "as received," "air dried," "dry coal," and "pure coal." Each form is useful for particular purposes, the "air dried" results being best adapted for general use.

The analysis of the sample "as received" shows the composition of the coal, including its moisture content, as received in sealed metal cans at the laboratory, and represents the composition of the coal in the mine. The analysis of the "air dried" sample shows the composition of the coal after a certain amount of its original moisture as mined has escaped. The loss is practically that which escapes on air-drying the coal, but in order to allow for the varying fluctuations of moisture in the air of the laboratory and to have the conditions of analysis uniform, the following procedure is adopted: The powdered coal is exposed in an oven in which a current of air at a temperature between 35° and 40° C. circulates; and the coal is weighed at intervals of three hours until the weight is practically constant. The analysis of "dry coal" shows the composition of the coal on a moisture-free basis. The analysis of "pure coal" shows the composition of the coal on an ash-free and moisture-free basis. All the figures are obtained by recalculating the results of a single analysis.

[a] Prof. Paper U. S. Geol. Survey No. 48, 1906, pp. 174 et seq.

[b] Washing and coking tests of coal: Bull. U. S. Geol. Survey No. 368, 1909.

Analyses of coal samples from the Trinidad coal field, Colorado.

[F. M. Stanton, chemist in charge.]

LAS ANIMAS COUNTY.

Laboratory No.	Location.				Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T. S.	R. W.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
345-D	....	....	....	....	0.6	As received	2.8	33.1	45.3	18.82	0.62	4.83	64.45	1.17	10.11	6,490	11,682
						Air dried	2.2	33.3	45.6	18.93	.62	4.79	64.84	1.18	9.64	6,529	11,753
						Dry coal	....	34.1	46.5	19.36	.64	4.65	66.29	1.20	7.86	6,675	12,015
						Pure coal	....	42.2	57.8	....	.79	5.77	82.20	1.49	9.75	8,277	14,898
115-D	NW. ¼ NE. ¼	29	33	63	1.2	As received	2.3	29.5	47.8	20.44	.64	4.59	65.00	1.13	8.20	6.508	11,714
						Air dried	1.1	29.8	48.4	20.68	.65	4.52	65.79	1.14	7.22	6,587	11,856
						Dry coal	....	30.2	48.9	20.91	.65	4.44	66.50	1.16	6.34	6,658	11,984
						Pure coal	....	38.2	61.8	....	.82	5.61	84.08	1.47	8.02	8,418	15,152
6312	SW. ¼ SE. ¼	36	33	64	1.1	As received	2.3	30.4	55.6	11.68	.63	5.04	71.91	1.14	9.60	7,327	11,389
						Air dried	1.3	30.7	56.2	11.81	.64	4.97	72.71	1.15	8.72	7,408	13,334
						Dry coal	....	31.1	56.9	11.96	.65	4.90	73.64	1.17	7.68	7,504	13,507
						Pure coal	....	35.4	64.6	....	.74	5.57	83.64	1.33	8.72	8,523	15,341
245-D	NE. ¼ SE. ¼	34	33	64	.9	As received	2.0	28.8	51.4	17.83	.67	4.61	69.46	1.08	6.35	6,930	12,474
						Air dried	1.1	29.1	51.8	17.99	.68	4.55	70.09	1.09	5.60	6,993	12,587
						Dry coal	....	29.4	52.4	18.18	.68	4.48	70.85	1.10	4.71	7,069	12,749
						Pure coal	....	35.9	64.1	....	.83	5.48	86.59	1.34	5.76	8,640	15,343
300-D	NE. ¼ NW. ¼	34	33	64	.3	As received	1.4	28.4	53.4	16.83	.72	4.36	69.99	1.05	7.05	7,070	12,726
						Air dried	1.1	28.5	53.5	16.88	.72	4.35	70.20	1.05	6.80	7,091	12,764
						Dry coal	....	28.8	54.1	17.08	.73	4.26	71.01	1.07	5.85	7,173	12,912
						Pure coal	....	34.7	65.3	....	.88	5.14	85.64	1.29	7.05	8,651	15,572
6310	NW. ¼ SE. ¼	33	33	64	1.0	As received	1.9	28.1	57.0	12.96	.68	4.56	72.15	1.13	8.52	7,285	13,113
						Air dried	.9	28.5	57.5	13.09	.69	4.49	72.88	1.14	7.71	7,359	13,246
						Dry coal	....	28.7	58.1	13.21	.69	4.43	73.54	1.15	6.98	7,426	13,367
						Pure coal	....	33.1	66.9	....	.80	5.10	84.73	1.33	8.04	8,556	15,501
6321	SE. ¼	25	33	65	1.9	As received	2.7	25.8	57.3	14.18	.61	4.63	71.08	1.09	8.41	7,139	12,850
						Air dried	.8	26.3	58.4	14.45	.62	4.51	72.46	1.11	6.85	7,277	13,099
						Dry coal	....	26.5	58.9	14.57	.63	4.45	73.03	1.12	6.20	7,335	13,203
						Pure coal	....	31.1	68.9	....	.74	5.21	85.48	1.31	7.26	8,586	15,455

6370	NE. ¼	26	33	66	1.5	As received	2.3	29.8	58.7	9.16	.50	5.22	74.24	1.08	9.80	7,655	13,781
						Air dried	.8	30.3	59.6	9.30	.51	5.13	75.37	1.10	8.59	7,773	13,991
						Dry coal	....	30.5	60.1	9.37	.51	5.09	75.97	1.11	7.95	7,834	14,101
						Pure coal	....	33.7	66.3	....	.56	5.62	83.83	1.22	8.77	8,644	15,559
116-D	....	......	......	......	1.7	As received	2.9	29.9	48.1	19.13	.77	4.61	65.28	1.06	9.15	6,511	11,720
						Air dried	1.2	30.4	48.9	19.46	.78	4.50	66.41	1.08	7.77	6,624	11,923
						Dry coal	....	30.8	49.5	19.69	.79	4.42	67.21	1.09	6.80	6,703	12,066
						Pure coal	....	38.4	61.6	....	.98	5.50	83.69	1.36	8.47	8,346	15,024
117-D	....	......	......	......	1.5	As received	2.7	31.2	50.1	16.03	.68	4.86	68.37	.99	9.07	6,870	12,366
						Air dried	1.2	31.7	50.8	16.27	.69	4.76	69.41	1.01	7.86	6,975	12,554
						Dry coal	....	32.0	51.5	16.47	.69	4.69	70.24	1.02	6.89	7,058	12,704
						Pure coal	....	38.4	61.6	....	.83	5.61	84.09	1.22	8.25	8,450	15,212
6455	....	18	32	68	2.0	As received	3.2	30.6	58.8	7.41	.67	4.76	75.74	1.10	10.32	7,540	13,572
						Air dried	1.2	31.2	60.0	7.56	.68	4.63	77.29	1.12	8.72	7,694	13,849
						Dry coal	....	31.6	60.7	7.65	.69	4.55	78.19	1.14	7.78	7,784	14,011
						Pure coal	....	34.2	65.8	....	.75	4.93	84.66	1.23	8.43	8,429	15,172
6458	NE. ¼	24	32	64	1.7	As received	3.1	28.0	50.6	18.34	.63	4.94	65.91	.93	9.25	6,594	11,869
	SW. ¼					Air dried	1.3	28.5	51.5	18.66	.64	4.83	67.05	.95	7.87	6,708	12,074
						Dry coal	....	28.9	52.2	18.92	.65	4.74	67.98	.96	6.75	6,801	12,242
						Pure coal	....	35.6	64.4	....	.80	5.85	83.84	1.18	8.33	8,388	15,098
6456	NE. ¼	36	31	65	2.3	As received	3.3	32.6	53.7	10.39	.74	5.30	72.61	1.24	9.72	7,329	13,192
	NE. ¼					Air dried	1.1	33.3	55.0	10.64	.76	5.16	74.32	1.27	7.85	7,402	13,504
						Dry coal	....	33.7	55.6	10.75	.76	5.10	75.09	1.28	7.02	7,580	13,644
						Pure coal	....	37.7	62.3	....	.85	5.71	84.13	1.43	7.88	8,493	15,287
152-D	W. ½	15	31	65	1.0	As received	3.2	34.0	51.2	11.57	.58	5.23	71.44	.99	10.19	7,123	12,821
						Air dried	2.2	34.3	51.8	11.69	.59	5.17	72.16	1.00	9.39	7,195	12,951
						Dry coal	....	35.1	52.9	11.95	.60	5.04	73.79	1.02	7.60	7,358	13,243
						Pure coal	....	39.9	60.1	....	.68	5.73	83.80	1.16	8.63	8,357	15,040
6528	NW. ¼	34	30	65	.7	As received	2.2	34.8	54.8	8.24	.72	4.97	75.11	1.21	9.75	7,453	13,415
						Air dried	1.4	35.1	55.2	8.29	.73	4.93	75.64	1.22	9.19	7,506	13,511
						Dry coal	....	35.6	56.0	8.42	.74	4.83	76.76	1.24	8.01	7,617	13,711
						Pure coal	....	38.9	61.1	....	.81	5.27	83.81	1.35	8.76	8,317	14,971
6536	NE. ¼	20	30	65	1.1	As received	2.4	35.1	56.4	6.06	.42	5.30	76.93	1.19	10.10	7,530	13,554
						Air dried	1.4	35.5	57.0	6.13	.42	5.24	77.79	1.20	9.22	7,614	13,705
						Dry coal	....	36.0	57.8	6.21	.43	5.15	78.84	1.22	8.15	7,717	13,891
						Pure coal	....	38.4	61.6	....	.46	5.49	84.06	1.30	8.69	8,228	14,810
6533	NW. ¼	9	30	65	2.3	As received	3.7	33.7	52.1	10.48	.64	5.30	70.93	1.19	11.46	7,025	12,645
	NE. ¼					Air dried	1.4	34.5	53.4	10.73	.66	5.16	72.60	1.22	9.63	7,190	12,742
						Dry coal	....	35.0	54.1	10.88	.66	5.08	73.63	1.24	8.51	7,293	13,127
						Pure coal	....	39.2	60.8	....	.74	5.70	82.62	1.39	9.55	8,183	14,729
6530	SE. ¼	5	30	65	1.4	As received	3.0	34.5	53.5	8.98	.35	5.08	71.98	1.31	12.30	7,185	12,933
	NW. ¼					Air dried	1.7	34.9	54.3	9.11	.36	4.99	73.00	1.33	11.21	7,287	13,117
						Dry coal	....	35.5	55.2	9.26	.36	4.89	74.24	1.35	9.90	7,411	13,340
						Pure coal	....	39.1	60.9	....	.40	5.39	81.81	1.49	10.91	8,167	14,701

Analyses of coal samples from the Trinidad coal field, Colorado—Continued.

HUERFANO COUNTY.

Laboratory No.	Location.				Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T. S.	R. W.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
6532	NE. ¼	30	29	65	2.8	As received	4.1	34.0	50.1	11.84	0.67	5.09	70.34	1.09	10.97	6,887	12,397
						Air dried	1.3	35.0	51.5	12.18	.69	4.92	72.37	1.12	8.72	7,085	12,753
						Dry coal		35.5	52.2	12.34	.70	4.84	73.34	1.14	7.64	7,180	12,924
						Pure coal		40.4	59.6		.80	5.52	83.67	1.30	8.71	8,191	14,744
6540	NE. ¼	24	29	66	1.9	As received	3.4	35.6	51.4	9.64	.75	5.24	70.96	1.23	12.18	7,108	12,794
						Air dried	1.5	36.3	52.4	9.83	.76	5.13	72.33	1.25	10.70	7,246	13,043
						Dry coal		36.9	53.1	9.98	.78	5.03	73.44	1.27	9.50	7,357	13,244
						Pure coal		40.9	59.1		.87	5.59	81.58	1.41	10.55	8,173	14,711
6541	NE. ¼	24	29	66	2.2	As received	3.6	34.5	50.3	11.58	.57	5.32	69.84	1.05	11.64	6,886	12,395
						Air dried	1.5	35.3	51.4	11.84	.58	5.19	71.41	1.07	9.91	7,041	12,674
						Dry coal		35.8	52.2	12.01	.59	5.10	72.46	1.09	8.75	7,144	12,860
						Pure coal		40.7	59.3		.67	5.80	82.35	1.24	9.94	8,119	14,614
6547	NE. ¼	17	28	66	4.4	As received	6.9	34.9	49.7	8.46	.53	5.45	69.15	1.02	15.39	6,710	12,078
	NW. ¼					Air dried	2.6	36.5	52.0	8.85	.55	5.19	72.33	1.07	12.01	7,019	12,634
						Dry coal		37.5	53.4	9.09	.57	5.03	74.27	1.10	9.94	7,207	12,973
						Pure coal		41.3	58.7		.63	5.53	81.69	1.21	10.94	7,927	14,269
240-D	NW. ¼	23	27	67	1.8	As received	6.0	35.5	39.6	18.86	1.04	4.92	58.30	.98	15.90	5,862	10,552
						Air dried	4.3	36.1	40.4	19.21	1.06	4.80	59.37	1.00	14.56	5,969	10,744
						Dry coal		37.7	42.2	20.08	1.11	4.52	62.05	1.04	11.20	6,239	11,232
						Pure coal		47.2	52.8		1.39	5.66	77.64	1.30	14.01	7,807	14,054
6551	SW. ¼	9	27	67	7.0	As received	10.2	34.3	43.8	11.65	.58	5.63	61.75	1.00	19.39	6,035	10,863
	NW. ¼					Air dried	3.4	36.9	47.2	12.53	.62	5.22	66.40	1.07	14.16	6,489	11,680
						Dry coal		38.2	48.8	12.97	.66	5.01	68.76	1.11	11.49	6,721	12,098
						Pure coal		43.9	56.1		.76	5.76	79.01	1.28	13.19	7,722	13,900
6608	NW. ¼	10	29	69	3.4	As received	6.4	35.2	47.5	10.87	.56	5.30	65.66	1.01	16.60	6,472	11,650
	SW. ¼					Air dried	3.2	36.4	49.1	11.25	.58	5.09	67.97	1.05	14.06	6,700	12,060
						Dry coal		37.6	50.8	11.62	.60	4.90	70.20	1.08	11.60	6,920	12,456
						Pure coal		42.6	57.4		.68	5.54	79.43	1.22	13.13	7,830	14,094

Data concerning samples of coal from Trinidad field represented by analyses.

LAS ANIMAS COUNTY.

Laboratory No.	Nearest town.	Name of mine.	Location in mine.	Section of coal bed represented by sample.	Kind of coal and condition of sample.
345-D	Wootton....	Red Robin........	....	....	Run-of-mine.
115-D	Engleville...	Engle.............	....	....	Do.
6312	Starkville...	Starkville.........	Room 6, entry G 4.	See page 397.......	Fresh, unweathered.
245-D	.....do......	Francisco.........	....	....	Run-of-mine.
300-D	Sopris.......	Piedmont..........	....	....	Do.
6310	.....do......	Sopris.............	Room 3, entry 17 W	See page 398.......	Fresh, unweathered.
6321	Cokedale....	Cokedale..........	Room 26, entry 4 W	See page 400.......	Do.
6370	Primero.....	Primero...........	Room 1, entry A 9.	See page 426.......	Do.
116-D	Tercio......	Tercio (bed No. 2).	....	....	Run-of-mine.
117-D	.....do......	Tercio (bed No. 3).	....	....	Do.
6455	Stonewall...	Clark's prospect...	100 feet from opening.	4 ft. 11 in.........	Slightly weathered.
6458	Trinidad....	Bowen............	Room 11, entry 2 N 6 E.	See page 401.......	Fresh, unweathered.
6456	Berwind....	Berwind No. 3....	Face of second south off entry 14 E.	*Ft. in.* Coal........ 4 Bone, discarded.... 1 2 Coal........ 4 4	Do.
152-D	Delagua.....	Delagua No. 2.....	....	....	Run-of-mine.
6528	Aguilar.....	Peerless annex....	Room 1, north entry.	4 feet............	Fresh, unweathered.
6536	.....do......	Las Animas No. 4.	Breast of workings.	4 feet.............	Do.
6533	Rugby......	Rapson...........	Face of entry 3 S..	See page 406.......	Do.
6530	Primrose....	Primrose..........	Room 3, entry 1½ N	See page 409.......	Do.

HUERFANO COUNTY.

Laboratory No.	Nearest town.	Name of mine.	Location in mine.	Section of coal bed represented by sample.	Kind of coal and condition of sample.
6532	Rouse.......	Rouse............	Face of entry 8 E..	See page 412.......	Fresh, unweathered.
6540	Pryor.......	Pryor lowest bed..	Face of entry 3 N..	*Ft. in.* Coal, bony, discarded. 3 Coal........ 1 6½ Coal, bony, discarded. 1 Coal........ 2 5 Coal, bony, discarded. 6	Do.
6541	.....do......	Pryor middle bed.	Entry 2 S., 150 feet from bottom of slope.	Coal, bony, discarded. 9 Coal........ 5 Shale, discarded .... 2½ Coal........ 4 3	Do.
6547	Walsenburg.	Robinson.........	Eighth cross entry off 8 N.	See page 415.......	Do.
240-D	Shumway...	Piñon No. 3.......	....	....	Nut coal.
6551	Strong......	Sunnyside........	Face of main slope.	See page 417.......	Fresh, unweathered.
6608	La Veta.....	Oakdale..........	Face of entry 3 S..	7 ft. 4 in..........	Do.

The table of analyses shows the following range and average composition of the samples from Las Animas and Huerfano counties on an air-dried basis:

Range and average composition (air-dried basis) of coal samples from Trinidad field.

	Las Animas County (18 samples).		Huerfano County (7 samples).	
	Range.	Average.	Range.	Average.
Moisture........................	0.8 - 2.2	1.30	1.3 - 4.3	2.54
Volatile matter..................	26.3 -35.5	31.44	34.5 -36.9	36.07
Fixed carbon....................	45.6 -60.0	53.83	40.4 -52.4	49.14
Ash.............................	6.13-20.68	13.43	8.85-19.21	12.24
Sulphur.........................	.36- .78	.64	.55- 1.06	.69
Hydrogen........................	4.35- 5.24	4.82	4.80- 5.22	5.08
Carbon..........................	64.84-77.79	73.89	59.37-72.37	68.88
Nitrogen........................	.95- 1.33	1.13	1.00- 1.25	1.09
Oxygen..........................	5.60-11.21	8.32	8.72-14.56	12.02
British thermal units............	11,753-13,991	12,920	10,744-13,043	12,227

These figures illustrate the well-known fact that the general product of the Trinidad field is a high-grade bituminous coal. It is comparable with the better coals of the Mississippi Valley and with many coals of the Appalachian region, and is distinctly superior to the product of most of the Rocky Mountain fields. The figures also show that the coal from Las Animas County is superior to that from Huerfano County. The coal from the northern part of the field is well adapted to domestic and steaming purposes, while that from the southern part makes a high-grade coke. It is the coking quality of the coal that gives the area under consideration special importance, for the Raton Mesa coal region is the chief area of coking coal west of Mississippi River.

The sulphur and moisture content of the coal throughout the field is low, sulphur in the air-dried samples ranging from 0.36 to 1.06 per cent. Moisture in the coal from two mines in the southern part of the field is less than 1 per cent, but toward the north the moisture content increases and in one mine in Huerfano County is more than 4 per cent. Ash, on the other hand, is generally rather high, averaging almost 13 per cent.

The ultimate analysis of pure coal, especially the percentage of carbon, affords data for judging the degree of metamorphism or devolatilization which the coal has undergone in its transformation from the original vegetable constituent matter. It is well known that in the process of coal making the carbon and hydrogen increases at the expense of oxygen and nitrogen, carbon ranging from about 55 per cent in peat to 95 per cent in anthracite. Inspection of the analyses of pure coal from the Trinidad field emphasizes the general high-grade character of the fuel, and the incomplete data at hand[a] indicate that the greatest metamorphism of the coal has occurred in the area adjacent to Purgatory River, southwest of Trinidad, where three tests show that the coal contains more than 85 per cent of carbon. The analyses show a general decrease of regional metamorphism from the southern part of the field northward, the total carbon ranging from 86 per cent in the south to 77 per cent in the north. But there are not enough analyses from all parts of the field, especially from the little-known interior portion, on which to base a more precise statement concerning the varying metamorphism.

These regional differences in composition are independent of local contact metamorphism by igneous rocks, of which there is abundant evidence in the Trinidad field. The metamorphosing effect on coal of both sills and dikes, however, appears to be local. Sills are much more destructive than dikes, for they affect a greater body of coal. In most places where sills are in contact with coal the bed is entirely

[a] The analyses represent coal chiefly from the margin of the field, samples from the interior being not available.

altered to natural coke and rendered commercially worthless. Dikes, on the other hand, affect a relatively small body of coal. A number of observations in mines show that generally the coal in the vicinity of a dike is coked only for a distance on each side about equal to the width of the dike. For instance, samples were collected for analysis in the eighth east entry of the new Rouse mine, in the vicinity of a dike, to determine the extent of its metamorphosing influence. There a dike 14 inches wide cuts across the coal bed, which is 63 inches thick. The coal has been coked on both sides of the dike for a distance of about 18 inches and prismatic structure is well developed in the coke perpendicular to the dike. The following analyses show that the coal has been distinctly altered by the dike and that the change from coke to coal is rather abrupt:

Ultimate analyses of natural coke and coal from Rouse mine.

[Moisture and ash free basis.]

	Natural coke 1 foot from dike.	Coal 1 foot from natural coke, 2½ feet from dike.	Coal 15 feet from dike.
Hydrogen	2.82	5.70	5.60
Carbon	91.41	81.98	81.51
Nitrogen	1.21	1.32	1.42
Oxygen	3.85	10.27	10.72
Sulphur	.71	.73	.75
	100.00	100.00	100.00

The following analyses give the composition of samples of natural coke and of typical coal from the Primero mine and from the Rouse mine:

Proximate analyses (dry-coal basis) of natural coke and coal, Primero and Rouse mines.

	Volatile matter.	Fixed carbon.	Ash.
Primero mine:			
Natural coke	8.3	80.9	10.8
Typical coal	30.5	60.1	9.4
Rouse mine:			
Natural coke	6,7	71.0	22.0
Typical coal	35.5	52.2	12.3

It is an interesting fact that although igneous rocks in the Trinidad field have coked the coal with which they have come into contact, anthracite coal, so far as the writer is aware, has not been found. It is probable, however, that in the deeply covered area contiguous to the great intrusive masses that form the Spanish Peaks profound changes of the coal have occurred.

The fact that this area has been the seat of great igneous intrusions suggests that the general quality of the coal has been materially affected by the igneous rocks. Yet comparison of analyses in connection with the distance of the samples from the center of intrusion—the Spanish Peaks—and consideration of the known limited metamorphosing effect of dikes cast doubt on the supposition of a direct connection of the igneous rocks with the general character of the coal. It appears more probable that regional influences, with which perhaps the intrusions of the igneous rocks were connected, caused the varied metamorphism of the coals; but the nature of the forces involved is a matter of speculation.

DEVELOPMENT.

HISTORY.

The presence of coal in the Trinidad field has been known since the early days of settlement, but the development of the field is of relatively recent date. Coal mining as an industry in Colorado is reported to have begun in 1864, when a production of only 500 tons was recorded. Statistics for the southern part of the State do not go further back than 1873, when the production of Las Animas County was grouped with that of Fremont County, the total for the two in that year being only 12,187 tons.

The development of the Trinidad field has been rapid, because of the superior quality of the coal. The earliest mines operated on a large scale were those at Starkville and Engleville, in the vicinity of Trinidad, and the Walsen, Robinson, and Cameron mines, near Walsenburg. For a number of years these were practically the only producers. During the period of general prosperity between 1887 and 1893 a number of new mines were opened along the eastern outcrop of the coal, including the Sopris, Berwind, Rouse, Hastings, Santa Clara, Forbes Canyon, Pictou, Peerless, and Brodhead. Branch lines from the Colorado and Southern and the Denver and Rio Grande railroads were built to these and other workings. Few new mines were started between 1893 and 1898, but the era of prosperity which terminated in 1907 and was checked only by the strike of 1903–4 witnessed a great development of the field. The production of the old mines was greatly increased and many new ones were opened. Purgatory Valley was made accessible by the construction of the Colorado and Wyoming Railroad and mines were opened at Primero, Tercio, and elsewhere. The northern part of the field was also actively developed by the extension of the Walsenburg-Pictou branch of the Denver and Rio Grande Railroad to Strong and Tioga, and the Piñon, Sunnyside, and other mines in that vicinity were opened.

The eastern outcrop of the coal has been well exploited and at present several score mines, whose locations are shown on the map (Pl. XX), are in operation. The western outcrop, however, because of its relative inaccessibility except at the north in the vicinity of La Veta and at the south in the vicinity of Tercio, is undeveloped. The interior of the basin, which constitutes the great reserve of the field, is almost untouched except for the few mines in the Morley and Purgatory districts. Great quantities of coal are yet to be obtained from mines located along the outcrop, but the future tendency will be to develop more and more the interior of the field by shafts, at first not far distant from the outcrop but later near the center of the basin.

MINING.

GENERAL CONDITIONS.

Conditions of mining in the Trinidad coal field are generally favorable. The climate permits unhampered outdoor work throughout the year. The water supply in a large part of the field is ample, timber is available near by, and the coal beds are in such a position as to be readily accessible and are easily worked.

The accessibility of the coal beds has been an important factor in determining the location of the principal mines, to which branch lines have been constructed from the main railroads. In some places where the coal outcrops high up in cliffs—for example, at the Bowen mine—the workings are reached by gravity planes, the main plant being situated in the adjacent lowlands, but most of the mines are located in good sites for camps. With few exceptions the mining companies have not only taken pains to construct economically efficient plants equipped with modern appliances, but have laid out the town sites in an attractive manner, with attention to general appearances and to sanitary conditions. In a number of camps the buildings are constructed of concrete and the hygienic conditions are admirable. The camps are generally equipped with waterworks, electric lights, etc., and are provided with churches, schools, and clubhouses.

WATER SUPPLY.

The Trinidad field is situated in the semiarid region, where the water supply is always an important factor, but the field lies near the base of the Sangre de Cristo Range and is watered by two perennial streams, Purgatory and Cuchara rivers; the intermittent streams which head in the vicinity of the Spanish Peaks, particularly Apishapa, Santa Clara, and Bear creeks, carry smaller amounts of water. The lofty Raton Mesa is also well watered, but the greater part of the field is destitute of surface water, being drained by arroyos that are generally dry except after torrential summer storms. The water-supply problem must therefore be solved in developing the interior part of the field. Much surface water can be saved by the construction of reservoirs, and it is probable that over a large part of the basin wells sunk to the Trinidad sandstone will strike water under pressure.

The camps adjacent to Purgatory Valley obtain their water supply from the river. In the western part of the field, near the headwaters of this stream, an abundance of good clear water is available, but farther downstream the supply becomes less in quantity and poorer in quality. A pumping plant at Segundo provides water for the coke ovens and settlement there and also furnishes water to the camp at Primero, about 2 miles north of the river. The water for the mine at Sopris also has to be pumped a considerable distance. At Cokedale water for the ovens is taken from the river and a better supply for domestic purposes is obtained by the construction of a subsurface dam across Reilly Canyon. By this contrivance the underflow of the creek is intercepted and pumped to a reservoir, from which it is distributed to the camp. In the southern part of the field the mines are usually dry and sprinkling is necessary to keep down the dust. The camps along the cliffs north of Trinidad are in general poorly supplied with water and for several of them water is hauled by tank cars from Trinidad, which has an excellent supply derived from the base of the mountains about 30 miles west of the city.

Farther north the large mines and coking plants in Road Canyon and in Canyon de Agua receive their supply by a pipe line from the abandoned Peerless mine, west of Aguilar. Between Apishapa Creek and Cuchara River there is an abundance of water in many of the mines, including the Peerless, Brodhead, Green Canyon, Rouse, Pryor, and Hezron. This water apparently has its source in the Trinidad sandstone, and in several places seems to come up along fault planes. (See p. 413.) In some of these mines powerful pumps have been installed. North of Walsenburg comparatively little trouble is caused by water and the supply from the mines is used in the camps, which otherwise would be poorly provided. In the new workings at the extreme north end of the field the water supply at present is insufficient and in some places water is hauled several miles from Huerfano River.

METHODS OF MINING.

The occurrence of the coal in an unsymmetrical basin necessitates different mining methods to meet the varied conditions. Along the eastern outcrop of the coal, where most of the mines are situated, the dip of the rocks is generally at a low angle to the southwest, the inclination rarely exceeding 10° and in many places being less than 3°. In the central part of the basin, where upper beds are worked by mines on the outcrop, the coal beds lie practically flat; and along the western outcrop of the coal the few mines that have been opened encounter steep dips, ranging from 40° to 90°.

There are no deep mines in the area here considered and only three shafts have been sunk, the deepest of which is 360 feet. The cover in most of the mines is not more than 300 or 400 feet, the greatest depth beneath the surface in any of the workings being about 1,100 feet at the southeast end of the Starkville mine. In the area contiguous to Walsenburg three beds of coal of workable thickness occur within a vertical range of 100 feet and several of the mines in that vicinity work all three beds. (See fig. 9.)

The roof in the mines varies. In a number of places it is a firm sandstone, but in others the roof is a weak shale, which causes trouble. A sandy shale is the most common material and in general makes a satisfactory roof. The floor is generally shale and gives little trouble except in places where the shale is so weak that in drawing pillars "squeezes" are likely to occur unless special precautions are taken. Variations in the thickness of the coal bed cause local "rolls," which in places require brushing of the roof to maintain proper grades.

Locally the workings are very extensive, for some of the mines have been in operation more than thirty years. In the Engle and Starkville mines, which are the oldest in the field, the workings, as already stated, occupy an area of about 3½ square miles. These two mines, the entrances of which are 2½ miles apart in an air line, are connected underground. From such dimensions the mines grade down in size to mere prospects. In 1907 there were 22 mines in the Trinidad field with a yearly output of more than 100,000 tons each.

The usual system of working is that of rooms and pillars with double entries. The entries are about 10 feet wide. The rooms vary considerably in size, but probably average 15 by 250 feet. The pillars between rooms are about 25 feet wide. The coal is generally shot from the solid, but in places it is undercut by pick and in a few mines, where cubical cleavage in the coal is well developed, as at Engleville and Starkville, shooting is not necessary and the coal is mined by pick only. Mining machines are not generally used, although in the northern part of the field they have been introduced to a slight extent. Along the western margin of the basin, where dips are steep, different methods are employed. At Tercio, where South Fork of Purgatory River has cut through the ridge, which is underlain by coal-bearing rocks that dip about 45° NE., an entry is driven on the outcrop parallel to the strike, with an air course about 20 feet above. The rooms, 25 feet wide, are driven up the rise, with 20-foot pillars. At the Occidental mine, west of La Veta, the coal, which is practically vertical, is reached by a tunnel. The entrance to the mine is located in a valley in the Pierre shale west of the coal measures, and the tunnel, about 300 feet long, penetrates the Trinidad sandstone before reaching the coal. The coal is worked by the stall-and-pillar system, with pillars about 15 feet thick. (See fig. 11.)

The methods of haulage vary with conditions. In most of the large mines where the dip is not too great the coal is hauled by means of electric motors using the trolley system. Rope haulage is employed on the steeper slopes. Mules are used chiefly for gathering the mine cars from the rooms to the main haulage ways.

Ventilation in connection with the double-entry system of mining is usually accomplished by exhaust fans operated either by steam or by electricity.

Gas, in greater or less quantity, is present in all the mines. In many it causes little or no trouble, but in others disastrous explosions have occurred.[a] Much of the danger seems to be in dust explosions which are started by the ignition of gas. Although in some of the more gaseous mines the use of safety lamps is obligatory this precaution is not sufficient, and where the workings are naturally dry care should be taken to lay the dust by an efficient system of sprinkling. It has been found that sprinkling the floors only is inadequate; the sides and roof also should be kept moist.

PREPARATION OF COAL FOR THE MARKET.

The "dirty" condition of the coal in this region generally necessitates some sorting before the product is marketable. Most of this work is done in the mines, the miners being required to discard "bony coal and impurities."

In the Trinidad district, where the greater part of the coal is coked, all that is so used is first washed. At some plants only the slack is made into coke, but where the entire output is coked the lump coal is crushed before washing. Results are different at the different plants, but the general conditions are indicated by the washing tests of coal from this field made at the government fuel-testing plant at Denver in 1907.[b] The following table shows the results of a number of tests:

Results of washing tests of coal from Trinidad field.

[Moisture-free basis.]

Source of coal tested.	Raw coal.		Washed coal.				Refuse.		
	Tons used in test.	Per cent of ash.	Tons obtained.	Per cent of raw coal used.	Per cent of ash.	Per cent of ash reduction.	Tons resulting.	Per cent of raw coal used.	Per cent of ash.
Engleville	9.30	20.91	6.60	71	13.17	37	2.70	29	36.59
Tercio	12.25	19.69	10.65	87	16.23	18	1.60	13	46.44
Delagua	6.64	11.95	6.00	90	9.74	19	.64	10	44.09
Shumway	5.86	20.08	4.80	82	13.32	34	1.06	18	33.33
Sopris	11.44	18.18	8.91	78	12.31	32	2.53	22	37.84
Hastings	17.04	19.62	13.67	80	12.05	39	3.37	20	44.58
Wootton	8.82	19.36	6.90	79	13.41	31	1.92	21	38.86

[a] See state coal-mine inspector's reports.
[b] Washing and coking tests of coal at Denver, Colo.: Bull. U. S. Geol. Survey No. 368, 1909, pp. 24–34.

The table shows that the percentage of ash in raw coal may be reduced about one-third by washing, and that the refuse is roughly 20 per cent of the coal used. About 60 per cent of the refuse is combustible matter.

At mines where the coal is not coked, principally in the northern part of the field, the coal is frequently hand sorted before shipping, and at Shumway it is proposed to install a washing plant to insure a better grade of domestic fuel.

The coal is usually put on the market in four grades—run-of-mine, lump, nut, and slack. The entire product of only a few mines is disposed of as run-of-mine; generally the coal is sized, both shaking and stationary screens being used. In this region there are no standard sizes for the several grades, and at each mine the practice is different. The most common sizes are as follows: Lump coal is that which passes over openings that vary in size between 1½ and 3 inches, nut coal passes over openings between three-fourths inch and 1¼ inches, and slack is that which passes through one-half to 1-inch openings.

COKE.

In 1907 a total of 937,451 tons of coke was produced in the Trinidad coal field at the following ten plants, all in Las Animas County:

Coke plants in Trinidad coal field.

Plant.	Number of ovens.	Owner.
Segundo	800	Colorado Fuel and Iron Company.
Tercio	600	Do.
Tabasco	302	Do.
Sopris	272	Do.
Elmoro	235	Do.
Starkville	190	Do.
Hastings	189	Victor Fuel Company.
Delagua	160	Do.
Gray Creek	100	Do.
Cokedale	300	Carbon Coal and Coke Company.

In November, 1907, the Elmoro washeries were totally destroyed by fire and those at Sopris suffered a similar fate in March, 1908. These plants consequently were not in use when the field was visited in 1908. The Tercio plant was also idle, and the coke ovens at Gray Creek were not in use; so that only six coking plants were then in operation, and the output of coke was considerably less than that of the previous year. In the manufacture of the 1907 output of coke, 1,547,848 tons of coal is reported to have been employed, making the ratio of coal used to coke produced approximately 61 per cent. The coal used in coke making in 1907 amounted to about 32 per cent of the total coal production of Las Animas County.

The large quantity of impurities contained in the coal makes it necessary that all of the product used for coke making be first washed. A considerable part of the coal used is slack, although a large part is run-of-mine. Ordinary 13-foot beehive ovens are in use throughout the field. At some plants mechanical coke pullers and other modern improvements are used, but in general a high grade of efficiency is not maintained. There are no fireproof washeries and no retort or underflue ovens in the field, so that all of the by-products and enormous quantities of heat are wasted. Conditions at Dawson, in the Raton field, where all of the heat used for the boiler plant is derived from the coke ovens and where there is an unusually efficient plant, might with advantage be introduced in the Colorado portion of the region.

The coke is a high-grade product which is used both in copper smelting and in the manufacture of iron and steel. The following tabulated statement of results at the government fuel-testing plant at Denver in 1907 and 1908[a] indicates general conditions. For further details Bulletin 368 and the papers noted on pages 379–380 should be consulted.

Coking tests of coals from the Trinidad field.

	Test 195 Engleville.	Test 221, Sopris.	Test 205, Tercio.	Test 217, Hastings.	Test 203. Delagua.
Date	12,2,07	2,12,08	1,4,08	2,3,08	12,30,07
Duration ... hours	64	44	37	38	54
Size:[b]					
As shipped	r. o. m.	r. o. m.	r. o. m.	sl.	r. o. m.
As used	½ in.	w., n. c.	w., f. c.	w., f. c.	w., f. c.
Coal charged:					
Wet ... pounds	13,310	12,000	10,970	9,940	12,970
Dry ... do	12,868	11,423	10,606	9,494	12,044
Coke produced:					
Wet ... do	9,000	8,367	7,380	6,450	7,650
Wet ... per cent	67.62	69.73	67.27	64.89	58.98
Dry ... pounds	8,932	8,347	7,345	6,413	7,596
Dry ... per cent	69.41	73.07	69.25	67.55	63.07
Breeze produced:					
Wet ... pounds	528	279	337	215	585
Wet ... per cent	3.97	2.32	3.07	2.16	4.51
Dry ... pounds	524	278	335	214	581
Dry ... per cent	4.07	2.43	3.16	2.25	4.82
Total yield:					
Wet ... do	71.59	72.05	70.34	67.05	63.49
Dry ... do	73.48	75.50	72.41	69.80	67.89
Physical properties of coke:					
Specific gravity—					
Apparent	1.05	1.08	1.00	1.04	.98
Real	1.92	1.93	1.93	1.91	1.86
Volume—					
Coke ... per cent	55.00	56.00	52.00	54.00	53.00
Cells ... do	45.00	44.00	48.00	46.00	47.00
Weight per cubic foot—					
Wet ... pounds	93.08	94.64	92.01	93.15	89.99
Dry ... do	65.00	67.21	62.06	64.47	60.69
6-foot drop test over 2-inch mesh—					
1 ... per cent	93.00	98.00	93.00	98.00	94.50
2 ... do	86.00	94.50	90.50	95.00	90.00
3 ... do	81.00	93.00	86.00	94.00	86.50
4 ... do	76.50	90.00	83.50	90.50	81.00
5 ... do	86.00	89.00	88.50	92.00	84.50

[a] Washing and coking tests of coal at Denver, Colo.: Bull. U. S. Geol. Survey, No. 368, 1909, pp. 34–53.
[b] r. o. m., Run-of-mine; sl., slack; w., washed; n. c., not crushed; f. c., finely crushed.

Remarks.—Test 195: Light-gray color with some little silvery coloration. Breakage good; long, large pieces. Cell structure, a little large. Metallic ring.

Test 221: Light-gray and silvery color; heavy deposit of carbon, probably cause of increased yield. Breakage good; long, large pieces. Metallic ring. Very heavy, good coke. Cells not so well closed as in coke from finely crushed coal.

Test 205: Light gray and silvery; large deposit of carbon. Cell structure good. Breakage good; long, large pieces. Metallic ring. Good, heavy coke.

Test 217: Light gray and silvery. Cell structure good. Breakage good. Good, metallic ring. Good, heavy coke. Charge ashed down about one-half inch over entire surface.

Test 203: Fingered. Dark coloration, but large deposit carbon. Cell structure small, not dense. Somewhat brittle and soft. Metallic ring. Good, heavy coke.

Chemical analyses of coal and coke in above tests.

Test No.	Laboratory No.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Phosphorus.
195	124-D	Coal	Wet	3.32	31.99	51.96	12.73	0.61	....
			Dry	....	33.08	53.75	13.17	.63	....
	130-D	Coke	Wet	.76	1.23	77.48	20.53	.44	0.0235
			Dry	....	1.24	78.07	20.69	.44	....
221	301-D	Coal	Wet	4.81	29.86	52.47	12.86	.63	....
			Dry	....	31.38	55.10	13.52	.66	....
	335-D	Coke	Wet	.24	.49	82.49	16.78	.81	.0140
			Dry	....	.49	82.68	16.83	.61	....
205	207-D	Coal	Wet	3.32	31.08	49.90	15.70	.72	....
			Dry	....	32.15	51.60	16.25	.75	....
	209-D	Coke	Wet	.47	.46	77.10	21.97	.66	.0217
			Dry	....	.46	77.46	22.08	.66	....
217	269-D	Coal	Wet	4.49	33.06	50.35	12.10	.65	....
			Dry	....	34.61	52.72	12.67	.68	....
	286-D	Coke	Wet	.57	.66	81.59	17.18	.57	.0077
			Dry	....	.66	72.06	17.28	.57	....
203	204-D	Coal	Wet	7.14	34.09	49.96	8.81	.50	....
			Dry	....	36.72	53.79	9.49	.54	....
	206-D	Coke	Wet	.70	1.62	82.69	14.99	.47	.1912
			Dry	....	1.63	83.27	15.10	.47	....

An interesting series of tests was made on coal from Shumway, Huerfano County, in the noncoking portion of the field. Four trials were made under different conditions, as shown in the following table, without producing coke:

Coking tests of coal from Shumway.

	Test 209.	Test 210.	Test 211.	Test 214.
Date	1, 19, 08	1, 20, 08	1, 22, 08	1, 30, 08
Duration ..... hours	80	36	43	60
As shipped	Nut.	Nut.	Nut.	Nut.
As used [a]	w., f. c.	w., f. c.	w., ⅝ in.	r., ⅝ in.
Coal charged:				
Wet ..... pounds	10,220	7,730	9,520	9,790
Dry ..... do	9,569	7,238	8,729	9,198
Coke produced	None.	None.	None.	None.

[a] w., Washed; f. c., finely crushed; r., raw.

Remarks.—Test 209: Charge burned very rapidly, but developed no cracks. At no stage was there any evidence of pasty condition or other signs of coking.

Test 210: Charge burned with small draft and exhibited only few widely separated cracks. Volatile driven off, but resultant product did not stick together.

Test 211: Effort to coke not crushed. Volatile driven off down about 12 inches and under this unburned coal.

Test 214: This test made to ascertain if washing might possibly have destroyed coking qualities. Volatile driven off as in test 211; no evidence of coking.

Chemical analyses of coal from Shumway used in the above tests.

Test No.	Laboratory No.	Condition of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.
209	241-D	Wet	6.37	37.11	44.57	11.95	0.89
210	241-D	Dry		39.63	47.61	12.76	.95
211	242-D	Wet	8.31	37.44	42.04	12.21	.84
		Dry		40.82	45.86	13.32	.92
214	240-D	Wet	6.05	35.45	39.64	18.86	1.04
		Dry		37.73	42.19	20.08	1.11

Tests were also made by mixing coal from Sopris with the coal from Shumway in an attempt to ascertain the possibility of producing coke from noncoking coal by the addition of good coking coal. The results seem to indicate that noncoking coal acts simply as a diluent.

Coking tests of mixed samples of coal from Sopris and Shumway.

	Test 220.	Test 224.
Date	2,9,08	2,14,08
Duration ... hours	25	22
Size:[a]		
As shipped	3-in. nut, r. o. m.	3-in. nut, r. o. m.
As used	w., f. c.	w., f. c.
Coal charged:		
Wet ... pounds	8,250	6,210
Dry ... do	7,814	5,809
Coke produced:		
Wet ... do	5,222	3,365
Dry ... do	5,216	3,318
Weight ... per cent	63.30	54.19
Dry ... do	66.75	57.12
Breeze produced:		
Wet ... pounds	177	513
Dry ... do	177	506
Wet ... per cent	2.14	8.26
Dry ... do	2.27	8.71
Total yield:		
Wet ... do	65.44	62.45
Dry ... do	69.02	65.83

	Test 220.	Test 224.
Physical properties of coke:		
Specific gravity—		
Apparent	1.11	1.00
Real	1.93	1.86
Volume—		
Coke ... per cent	58.00	54.00
Cells ... do	42.00	46.00
Weight ... per cubic foot—		
Wet ... pounds	95.36	90.18
Dry ... do	69.15	61.49
6-foot drop test over 2-inch mesh—		
1 ... per cent	97.50	96.50
2 ... do	93.00	94.00
3 ... do	90.50	88.50
4 ... do	89.00	84.00
5 ... do	90.50	84.50

[a] r. o. m., Run-of-mine; w., washed; f. c., finely crushed.

Remarks.—Test 220: Proportions 1 to 3. Coke light-gray color. Cell structure good. Breakage cross fractured and irregular, but pieces of good size; 6-inch cubes. Mixture of noncoking Shumway coal appears to have opened cells.

Test 224: Proportions 2 to 1. Coke dull-gray color; soft, dense, punky. Cell structure exceeding small, only visible by means of magnifying glass. Breakage very poor and irregular, cohesion slight. Percentage of breeze very large.

That the coal in the southern part of the field will coke and that in the northern part will not is an interesting and economically important fact, but the cause of the difference is not known. The reason why some coals can be made into coke and others can not has long been a mystery. New light has recently been thrown on the subject by David White,[a] who suggests that the coking property

[a] White, David, The effect of oxygen in coal: Bull. U. S. Geol. Survey No. 382, 1909, pp. 48–54.

of some coals at least is due to the presence of gelatinous algæ in the original ingredient matter of which the beds are composed. The presence of such ingredients, he affirms, would tend to cause relatively high hydrogen and low oxygen, features that have been observed to characterize coking coals. White suggests that the hydrogen-oxygen ratio on a dry-coal basis indicates whether a coal will coke or not, and states that if the ratio (H:O) is 59 per cent or more the coal is "almost certain to possess coking fusibility," the figure being obtained by empirical tests. So far as the Trinidad field is concerned it is a fact that the hydrogen-oxygen ratio of the coking coals is greater than 59 per cent and that of the noncoking coals is less. In such an area as the Trinidad field, however, where there is coking coal at one end of the basin and noncoking coal at the other end, and where there can be no doubt that the coals in the two portions of the field, if not actually the same beds, certainly belong to the same group, it seems more likely—at least in the absence of data to the contrary—that the varied coking quality is due not so much to differences in original ingredient matter as to differences in the metamorphic action to which different parts of the basin have been subjected; but the entire subject is very obscure. It is noteworthy that the analyses show a distinct difference in composition of the coals in the northern and southern areas of this field—a fact which suggests, as already stated, that the coking quality of the coals is connected with the general regional metamorphism that the beds have undergone. The coking coals of the southern part of the field are the more highly altered beds, containing relatively more carbon and hydrogen and less oxygen, the noncoking coals in the north being less metamorphosed.

STATISTICS.

AMOUNT OF AVAILABLE COAL.

Because of the varied occurrence of the coal, the uncertain amount which has been made useless by the intrusion of igneous rocks, and the large unexploited central area, it is impossible at present to estimate at all closely the total available quantity. The following figures therefore are only a very rough approximation.

The area included by the outcrop of the lowest coal group between the state boundary on the south and an arbitrary line across the north end of the field is 1,115 square miles. Of this about 80 square miles in the vicinity of the Spanish Peaks may be considered negligible both on account of the great depth[a] of the coal beneath the surface and on account of its destruction, in part of the area, by the intrusion

[a] In estimating the extent of this excluded area, a depth of 3,000 feet has been regarded as the maximum limit to which coal can be profitably mined under present conditions in this country.

of a great volume of igneous rocks. The area of available coal land, therefore, in the Trinidad field is about 1,035 square miles. To obtain a conservative estimate it can be assumed that the total amount of coal of workable thickness may be represented by a single bed 5 feet thick extending throughout the field. This figure is the average of 106 measurements of coal beds in the lower group. In the estimate the coal in the middle and upper groups is considered as offsetting the destructive effect of igneous rocks. On the basis of one bed of coal 5 feet thick occupying an area of 1,035 square miles, there was originally 5,860,998,000 short tons of coal in the Trinidad field.

PRODUCTION AND VALUE.[a]

In 1908 Colorado ranked sixth among the States in the value of its coal production and eighth in the amount of coal produced, the output of the State being 9,634,973 short tons, valued at $13,586,988. These figures, on account of the unfavorable trade conditions due to the business panic, are considerably less than those for 1907, but advance data indicate that the tonnage for 1909 exceeded that of 1907, which was the largest in the history of the State. Of the total amount mined in 1908 the Trinidad coal field produced 5,834,869 short tons, valued at $7,499,159, which is more than 62 per cent of Colorado's total tonnage. The following table shows the production and value of coal mined in the Trinidad field from 1892 to 1908, inclusive:

Production and value of coal in the Trinidad field, Colorado, 1892 to 1908.

Year.	Las Animas County.			Huerfano County.	
	Quantity.	Made into coke.	Total value.	Quantity.	Value.
	Short tons.	*Short tons.*		*Short tons.*	
1908	4,190,801	1,113,450	$4,854,651	1,644,068	$2,644,508
1907	4,885,105	1,547,848	5,658,606	1,797,790	2,799,133
1906	4,768,882	1,666,924	4,856,949	1,803,791	2,502,924
1905	4,297,599	1,844,441	4,257,186	1,426,640	1,958,148
1904	2,808,953	848,182	2,977,215	1,187,905	1,754,904
1903	3,213,743	1,106,798	3,191,565	1,319,666	1,757,722
1902	3,245,271	1,234,470	2,919,146	1,189,313	1,446,866
1901	2,476,138	801,108	2,197,567	918,609	1,063,403
1900	2,123,411	749,222	1,808,996	854,944	912,110
1899	2,125,143	647,610	1,863,876	632,577	727,781
1898	1,211,340	354,292	1,100,022	1,075,881	1,185,244
1897	1,427,526	337,670	1,359,022	367,894	402,773
1896	1,261,555	306,185	1,185,113	353,338	375,228
1895	1,253,149	303,351	1,212,527	386,696	402,905
1894	1,153,863	316,449	1,167,174	408,045	441,130
1893	1,587,338	336,735	1,610,366	521,205	600,651
1892	1,171,069	295,106	1,433,897	541,733	1,083,466
	43,200,886	13,809,841	43,653,878	16,430,095	22,058,896

Prior to 1892 complete data were not kept, but from the figures available, which go back to 1873, it is estimated that the total production of the Trinidad field down to and including 1908 is, in round numbers, 68,800,000 tons.

[a] Mineral Resources U. S. for 1908, pt. 2, U. S. Geol. Survey, 1909.

ISOLATED COAL FIELDS IN SANTA FE AND SAN MIGUEL COUNTIES, NEW MEXICO.

By James H. Gardner.

INTRODUCTION.

In the early spring of 1908 the writer examined certain isolated coal fields in Sandoval, Santa Fe, and San Miguel counties, N. Mex., in connection with the classification of public lands. The fields visited were the Una del Gato, Cerrillos or Madrid, Omara, and Pecos River. The first three are probably detached portions of a once continuous field which covered a wide area previous to the uplift of the Ortiz and neighboring mountains. A brief report on the Una del Gato field, by M. R. Campbell,[a] was published in 1907. The Cerrillos or Madrid region has been visited by numerous geologists and well described in a report by D. W. Johnson[b] for the Columbia School of Mines. The Madrid anthracite has attracted the attention of mining men and scientists for many years. It is the result of a local intrusion of andesite that through heat and pressure has metamorphosed subbituminous coal to high-grade bituminous and anthracite. The reports, above cited, on the Una del Gato and Cerrillos fields are fully descriptive of those fields, and it is scarcely necessary to add to them in this brief paper.

OMARA COAL FIELD.

The Omara coal field is a small area of coal-bearing rocks located about 16 miles by wagon road southeast of Madrid and about 12 miles northeast of San Pedro. The larger amount of the output of the field has been used at San Pedro by the Santa Fe Gold and Copper Company. The area of workable coal so far as determined is confined to sec. 32, T. 13 N., R. 9 E., New Mexico principal meridian. Only one mine is in operation—the Block Coal or Omara mine, operated by the Lewisohn Coal Company. This mine, which is located in the N. ½ SE. ¼ SW. ¼ sec. 32, has been worked intermittently for a

[a] The Una del Gato coal field, Sandoval County, N. Mex.: Bull. U. S. Geol. Survey No. 316, 1907, pp. 427-430.

[b] Geology of the Cerrillos Hills, New Mexico: Columbia School of Mines Quart., 1907, pp. 303-350.

number of years. A slope enters in a direction N. 60° E., at a slight dip, on a bed 30 inches thick. This bed has a massive sandstone cover 9 feet thick, above which is a second coal bed 4 feet 6 inches thick, also capped by a massive sandstone. Apparently these sandstones are of fresh-water origin; their direct contact with underlying coal beds suggests either an abrupt change in the physiography of the region at the end of each coal-forming period or a slight unconformity. The two beds are very inconstant in thickness. At one point, 560 feet down an old slope on the upper bed near the present mine, the coal abruptly disappeared against a solid face of sandstone, showing no evidence of a fault. The entry was turned in another direction and the workings were continued. The writer, in company with Norberto S. Torres, superintendent of the mine, entered the old slope and made an examination of this portion of the workings. It was found that the disappearance of the bed was due to the total erosion of the coal previous to the deposition of the overlying sandstone, which is thus brought into juxtaposition with the floor of the coal bed. This is a condition which is likely to be encountered where a massive sandstone rests directly on a coal bed.

The following is the section exposed at the Block Coal mine:

Section of coal bed in Block Coal mine.

	Ft.	In.
Covered by débris from Santa Fe formation.		
Sandstone, massive	?	
Coal	4	6
Sandstone, massive	9	
Coal	3	
Shale, hard, dark.		
	16	6

The coal of these beds is black, bright, and hard, being similar in appearance to the bituminous coal of the Madrid district. At a distance of 350 feet N. 60° E. down the main entry a basaltic dike 45 feet thick was encountered. This dike, with a nearly north-south strike, stands above the surface as a prominent wall in the western part of sec. 32. The main entry was driven straight through the dike and the coal bed was found in normal position on the east side. Workings on the upper bed also were begun east of the dike. For a distance of 20 feet on either side of it the coal is harder and more nearly semianthracite, and the coal in immediate contact with the basalt is slightly prismatic in structure, but on the whole the coal has apparently been very slightly altered by this intrusion. It is probable that the general quality of the entire bed as exposed by the underground workings has been improved by thermal conduction from this dike, transmitted either through the coal itself or through the massive sandstone covers of each bed. As the thermal conductivity of dry sandstone is about five times the maximum conductivity of coal,[a] it is highly probable that at points distant from the dike the coal would be appreciably affected by heat conducted through the sandstones lying directly on the coal beds.

The Omara field is apparently confined to a very small area surrounding the mine. A quarter of a mile south and west of the mine a massive sandstone is exposed which occurs about 100 feet below the coals. Below this is a broad level plain of shale of Montana age stretching away to the southwest toward the southern part of the Ortiz Mountains. On the northwest and southeast, at distances of less than a mile each, the coal field is apparently limited by faults but is largely concealed by débris from the Santa Fe formation. The Santa Fe is of Tertiary age and lies unconformably over the older geologic formations. These beds were named by Hayden, who visited the Cerrillos district in 1869.[b] Johnson[c] has shown, by a detailed study of these unconformable beds and of the general physiography of the region, that they are the result of confluent alluvial fans from the surrounding mountains and extend in age from the Loup Fork (Tertiary) to the present time.

The Omara coal field is limited by the large basaltic intrusion of Pelon Mountain, less than a mile to the northeast. It seems highly probable that workable coal will not be found in the district except from the central portion of sec. 32 northward to the north line of sec. 29. As each of the coal beds is capped by a massive sandstone, it is impossible to say from a surface examination what conditions may be met in the underground workings. The coal-bearing formation is probably of the same age as the beds in the Madrid field and corresponds closely, if not exactly, with the Mesaverde formation of the San Juan Basin.

CARBONIFEROUS COAL ON PECOS RIVER.

In April, 1908, the writer inspected areas of reported coal in Tps. 16 and 18 N., R. 12 E. An abandoned drift is located in the E. ½ NE. ¼ SE. ¼ sec. 5, T. 16 N., R. 12 E., in the west cliffs of Pecos River about 5 miles above the town of Pecos. This drift, formerly known as the Gould & Thomas mine, enters in a direction N. 65° W. on a very irregular coal bed, showing an average thickness of 20 inches. About 120 feet from the surface the bed thickens locally to 40 inches, but 225 feet back it shows only 10 inches. It was readily seen that this coal bed occurs in the Carboniferous system, and this observation was later verified by a collection of Pennsylvanian fossil invertebrates from the rocks both above and below the coal bed.

[a] Everett, J. D., C. G. S. system of units, London, 1891, pp. 125-127.
[b] U. S. Geol. Survey of Colorado and New Mexico, preliminary field report, 1869, pp. 66-68.
[c] Johnson, D. W., op. cit., pp. 328-332.

The following is a generalized section along the river above Pecos:

Generalized section along Pecos River above Pecos, N. Mex.

	Feet
Sandstone, shale, local conglomerate and limestone, the whole variegated, red predominating	?
Limestone with some alternating shale and sandstone	100
Limestone containing *Derbya cymbula*, *Derbya bennetti*, *Productus inflatus* (?), *Productus inflatus?* var., *Spirifer rockymontanus*, *Spirifer cameratus*, and *Composita subtilita*	5
Limestone with some alternating shale and sandstone	1,000
Limestone containing *Derbya bennetti*, *Productus inflatus?* var., *Spirifer rockymontanus*, *Composita subtilita*, and *Cliothyridina orbicularis*	5
Limestones with some alternating shale and sandstone	350
Limestone containing *Derbya bennetti*, *Productus inflatus?* var., *Spirifer rockymontanus*, and *Composita subtilita*	5
Limestone, massive	50
Limestone, shaly, containing *Zaphrentis* sp., *Productus inflatus?*, *Productus inflatus?* var., *Productus* aff. *wallacianus*, *Marginifera* aff. *muricata*, *Marginifera* aff. *splendens*, *Rhynchopo raillinoisensis*, *Spirifer rockymontanus*, *Squamularia perplexa*, *Cliothyridina orbicularis*, *Hustedia mormoni*, and *Phillipsia* sp	1⅔
Sandstone, calcareous	3
Shale	1
Coal	Varying.
Limestone and sandstone	30
Shale containing *Derbya bennetti*, *Productus inflatus?* var., *Spirifer rockymontanus*, and *Composita subtilita*	10
Covered, about	200
Limestone, about	50
Pre-Cambrian complex.	
	1,810⅔

George H. Girty is disposed to think that the fossils indicate rocks rather low in the Pennsylvanian series.

Another prospect drift was visited in the NE. ¼ NE. ¼ sec. 28, T. 18 N., R. 12 E. This is also in the west cliffs of Pecos River. It was opened in 1905 by O. W. Alexander, manager for the Pecos Copper Company, located at Cowles. The coal bed is reported as being too thin and the coal too poor in quality to be of commercial value. The following is the section at the mine:

Section of coal bed in Cowles mine, in sec. 28, T. 18 N., R. 12 E.

	Ft.	in.
Limestone.		
Sandstone, massive	7	
Shale	1	
Coal		7–15
Shale		6
Shale, sandy.		
Covered.		

A sample of the coal was sent to the Survey laboratory at Pittsburg, Pa., where the following analyses were made under the direction of F. M. Stanton:

Analysis of coal from Cowles mine.

[Laboratory No. 6862. Air-drying loss, 0.90 per cent.]

	As received.	Air dried.	Dry coal.	Pure coal.
Moisture	1.72	0.83	....	....
Volatile matter	22.27	22.47	22.66	30.23
Fixed carbon	51.39	51.86	52.29	69.77
Ash	24.62	24.84	25.05	....
Sulphur	2.75	2.78	2.80	3.74

It will be seen from the above analysis that the coal is very high in ash. Owing to its low grade as a fuel and the very meager quantity available, it is of little commercial importance at the present time.

The coal beds of the Pecos River region are extremely interesting geologically. The limestone, sandstone, and shale with which these beds are associated are the lowest and oldest of the stratigraphic section in this region. They rest directly on the pre-Cambrian complex that is exposed farther west in the Santa Fe Mountains. As they are positively correlated with the Pennsylvanian of the East, it is interesting to note that even though they are in large part marine, still the presence of coal beds in them indicates that conditions prevailed here for a time such as characterize the series in the eastern part of the United States.

THE CARTHAGE COAL FIELD, NEW MEXICO.

By James H. Gardner.

INTRODUCTION.

The following brief report contains the results of an examination of the Carthage coal field, New Mexico, in February, 1908, relative to the classification of public lands in that area. The Carthage field is located 12 miles southeast of San Antonio, Socorro County, in T. 5 S., R. 2 E. One of the first coal mines in New Mexico was opened in this field in 1861 by government troops encamped on the Rio Grande; the same mine is in operation to-day and is known as the Government mine.

As this field is located some distance from the main line of travel along the valley of the Rio Grande, the problem of transportation has given considerable trouble and the facilities for placing the coal on the market have varied greatly from time to time. In 1881 the Santa Fe Railway Company built a branch line to the field, but this line was operated only until 1894, when it was abandoned on account of a seemingly well-authenticated report that the coal beds were about exhausted. This report, however, seems to have been without foundation, for later and more careful examinations of the region revealed the presence of workable coal in considerable quantity and mining was resumed; but the operators were badly handicapped by having to haul their coal in wagons 12 miles to San Antonio in order to send it to market. The mines were operated on this basis until August, 1906, when the New Mexico Midland Railroad was built along the same right of way as the old branch of the Santa Fe. This new line, operated by the Carthage Fuel Company, delivers to the Santa Fe Railway, which offers an all-rail route for the coal from Carthage to El Paso and other places in the South and Southwest. There are now four active mines in the field—the Government, Bernal, and Hilton mines of the Carthage Fuel Company and the Emerson mine of Emerson & Allaire. The operators of the Emerson mine still haul their coal in wagons to the railroad at San Antonio.

GENERAL GEOLOGY.

STRATIGRAPHY.

The coal-bearing rocks of the Carthage field (see Pl. XXI) as revealed by the drill contain the Carthage coal bed, with an average thickness of 5 feet, besides several small beds from 1 inch to 8 inches thick. All the mines of the field are on the Carthage bed, opened originally at the Government mine. The geologic age of these coal beds has been a disputed question. The writer collected fossil invertebrates both above and below the Carthage bed which were examined by T. W. Stanton. The fossils found below the coal bed consist of species characteristic of the Benton fauna and agree with collections previously obtained in the neighborhood of Carthage by Willis T. Lee and others. The fossils obtained 35 feet above the coal are brackish-water forms, consisting mostly of types which range from a horizon near the base of the Colorado up to the Laramie. Doctor Stanton states, however, that he believes the coal to be older than the Laramie and probably to lie within the limits of the Montana. This suggestion agrees with the conclusions resulting from the writer's studies of the stratigraphy and correlations based entirely on lithologic evidence. The character of the coal-bearing formation and its conformable relations to the underlying shale, which contains a Benton fauna, strongly suggest that it is either upper Colorado or lower Montana. The similarity of the coal-bearing formation to that of other fields of New Mexico, the geologic age of which is known, leads the writer to believe that it is Montana and in age corresponds closely if not exactly with the Mesaverde formation of the San Juan Basin.

The Carthage field is the southernmost of the productive coal fields in this portion of the Southwest. The so-called Engle coal field[a] lies 70 miles farther south, but as yet no coal bed of workable thickness has been reported from that district. The relation of the coal-bearing formation of the Carthage field to that of the Engle field is not known, but it is probable that they are of approximately the same age.

In the vicinity of Carthage a series of red and variegated shales, sandstones, and coarse conglomerates rests unconformably upon the coal-bearing formation, which consists of tan-colored sandstone and drab shale. These variegated beds dip to the south and east beneath late Pleistocene clay, sand, gravel, and sedimentary débris that cover the whole interior of the great desert synclinorium known as the Jornada del Muerto and form prominent terraces in the valley of the Rio Grande. In this part of the Jornada del Muerto the Pleistocene beds contain notable amounts of gypsum that may have been eroded from immense deposits some 20 miles northeast of Carthage, occurring probably in the Carboniferous system.

[a] Lee, W. T., The Engle coal field, New Mexico: Bull. U. S. Geol. Survey No. 285, 1906, p. 240.

This recent unconsolidated material obscures the underlying variegated beds and coal-bearing formation throughout the region bordering the Carthage field. At Carthage the underlying rocks are brought to the surface by a comparatively recent disturbance which produced an extremely complex and irregular system of faults. The writer was fortunate in finding fragments of bone and one tooth of a mammal in the variegated beds overlying the coal-bearing formation. The tooth was reported as possibly *Palæosyops* by J. W. Gidley, who regards it as certainly of later age than the Wasatch epoch and probably about the same as the Bridger. Because the variegated beds (Tertiary) have been confused with the much older red beds of the upper Carboniferous and Triassic (?) systems the area of the coal-bearing formation has been considered by many to be of very small extent. The variegated shale and sandstone under which the coal-bearing rocks dip on the south and east sides of the field have been erroneously considered as belonging normally below the coal-bearing formation and as having been faulted up to the present surface. A careful examination, however, revealed the facts that they contain fossils characteristic of the Bridger formation and that the coarse conglomerate composed of a varied mixture of water-worn sedimentary fragments contrasts very distinctly with the much older Triassic (?) (Jurassic) or Carboniferous [a] beds below.

The following section presents the stratigraphic succession in the Carthage region:

General section of rocks in the Carthage region.

	Feet.
Pleistocene:	
Caliche, white, fine, siliceous	5
Clay and sand, unconsolidated material of Rio Grande valley and Jornada del Muerto	1,000
	1,005
Unconformity.	
Eocene:	
Shale and sandstone, variegated	700
Conglomerate, very coarse bowlders, granite, and sedimentary débris, Carboniferous limestone fragments, etc	200
Shale, red, some sandstone	70
Sandstone, red, very coarse grained, bone fragments and tooth at top	30
Conglomerate, quartz, sandstone, granite, chert, in coarse matrix of granite débris	3
Sandstone, red, some shale	10
Conglomerate, small quartz pebbles	5
Shales, red and drab	5
	1,023
Unconformity.	

[a] For a description of the lower red beds see Lee, W. T., Note on the red beds of the Rio Grande region in central New Mexico: Jour. Geology vol. 15, No. 1, 1907.

	Feet.
Montana:	
Sandstone, tan-colored and drab shale with traces of coal	600
Shale and thin beds of sandstone. Top contains *Ostrea* sp., *Anomia micronema* Meek?, *Modiola* related to *M. regularis* (White), *Corbicula*? sp., *Corbula* sp., *Melania* sp., and *Admetopsis*? sp	40
Coal, Carthage	5
Shale, drab	20
Sandstone, massive, brown	20
	685
Colorado:	
Shale, drab, with yellowish lime concretions	120
Shale, yellowish, with brown sandstone	45
Sandstone, massive, soft, brown, fossiliferous, containing *Ostrea* sp., *Ostrea lugubris* var. *belliplicata* Shumard, *Pinna* sp., *Pholadomya* sp., *Fasciolaria*? sp., *Prionotropis woolgari* (Mantell)? and *Coilopoceros colleti* Hyatt	15
Shale, drab	40
Shale, drab, with thin brown sandstone	135
Sandstone, massive, gray	10
Sandstone and shale; in center fossiliferous sandstone containing *Inoceramus labiatus*, *Cardium* sp., *Cyprimeria* sp., *Psilomya* sp., *Gyrodes* sp., *Fasciolaria*? sp., and *Volutoderma*? sp	30
Shale, drab	500
	895
Dakota (?):	
Sandstone, hard, gray, in bold hogback, some thin shale	200
Triassic (?):	
Sandstone, dark red, with red and drab shales	1,300
Shale, gray, with pinkish chert inclusions, minute bone fragments	20
Shale, red, and some sandstone	260
Sandstone, red, and red shale	100
Conglomerate with coarse quartz pebbles, dark, white, and yellow	15
Shale, variegated, and red sandstone	300
	1,995
Carboniferous:	
Limestone, bluish-gray, weathers yellowish. Could possibly be used with higher shale for manufacture of Portland cement	200
Grand total	6,003

TOPOGRAPHY AND STRUCTURE.

The Carthage coal field is situated in the highlands dividing the present Rio Grande valley from the desert plains of the Jornada del Muerto. The average altitude of the coal fields is about 5,000 feet, that of the mouth of the slope at the Government mine being 5,032 feet. The topography is that of a plains region, slightly elevated, faulted, and subsequently eroded. Cuestas, or sharp ridges, with the abrupt face along the fault plane and the other face sloping more gently with the dip of the strata, are the prevailing topographic and structural features. These cuestas lie with their longer axes in every conceivable direction and cut across one another without definite system.

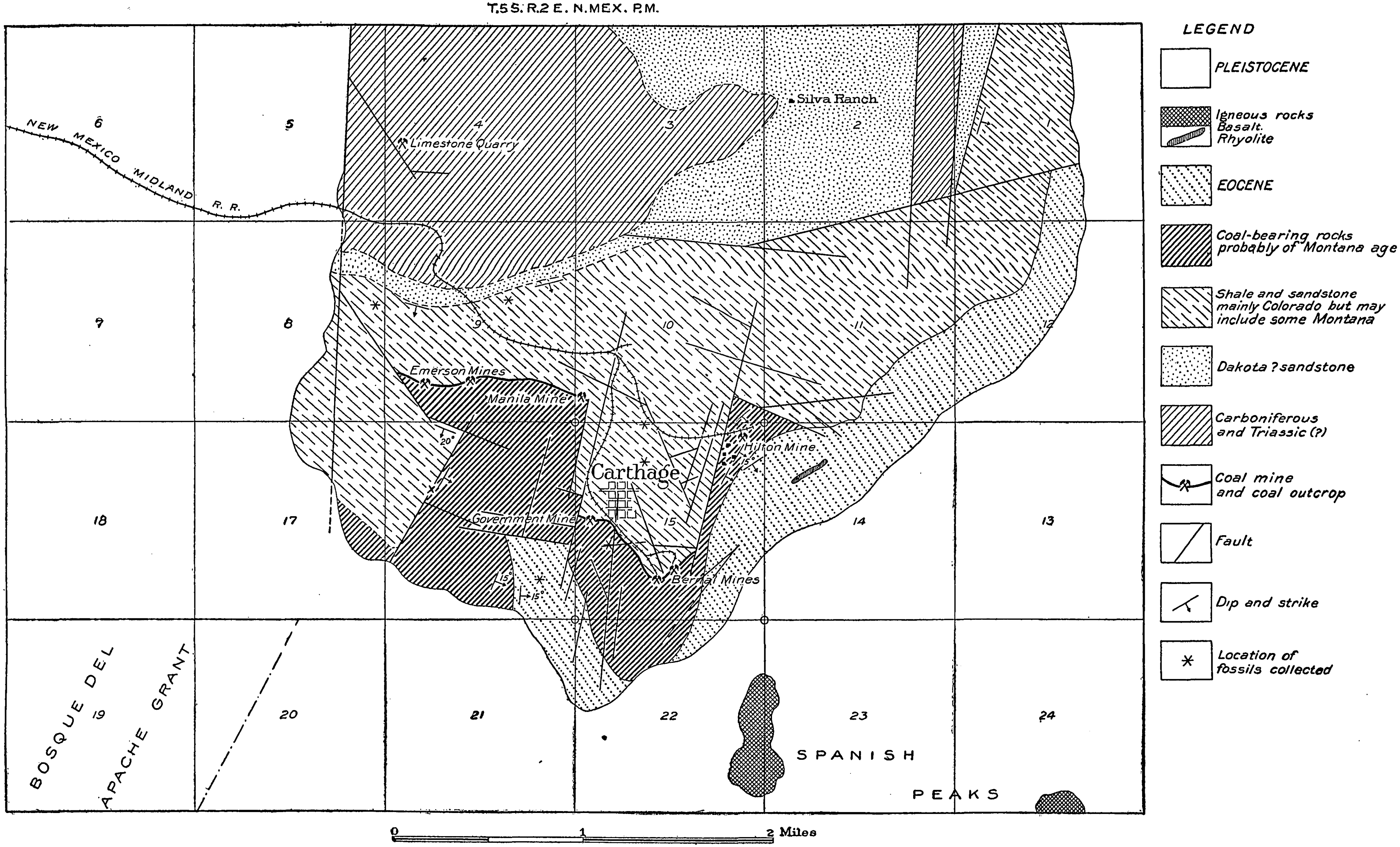
In working the coal mines almost innumerable faults have been encountered. It is often with extreme difficulty that the coal bed, lost at some prominent fault, is discovered in the block beyond. In places entries have been driven ahead in solid sandstone in order to keep the haulage gradient. On account of the numerous faults and changes in dip there is no definite method in extending the underground workings. Even though the mines are in an arid region, considerable expense is entailed on the operators at depths below 200 feet on account of water rushing in along the fault planes and gathering in the lower workings.

It is the writer's opinion that the Carthage field is an exposed continuation of a larger area of coal-bearing rocks lying to the east beneath the Jornada del Muerto.

IGNEOUS ROCKS.

In the southeast quarter of T. 5 S., R. 2 E., there are several prominent volcanic necks consisting of dark basalt, which are known as Cerro Colorado, from local exposures of variegated or reddish rocks reported as occurring around their southern boundary, and also as Spanish Peaks, from their resemblance in form to the peaks of that name in southern Colorado. These peaks are of very recent date and no doubt belong to the same epoch of eruption as the volcanic necks in the vicinity of Engle and the basaltic flows near Albuquerque, San Marcial, and La Mesa, west of Mesilla Valley.

In the NW. ¼ sec. 14, just east of the Hilton coal mine, there is a mass of grayish and pink acidic igneous rock which appears to be conformable with the inclosing variegated beds, dipping 15° south of east. The gray rock is a finely porphyritic, holocrystalline variety of hornblende andesite with augite and biotite in less proportions. It contains accessories of magnetite and apatite and considerable secondary calcite and chlorite. The pink rock is similar to the gray variety, but is in the form of a tuff deposited with the variegated beds.



MAP OF CARTHAGE COAL FIELD, NEW MEXICO.

By J. H. Gardner.

This rock is probably of the same age and character as the older effusive masses of the Jemes Mountains, the Socorro Mountains, Cerro Magdalen, and the Dona Ana Hills.[a] The fact that a portion of the rock occurs in the form of a tuff bedded with the variegated clay and conglomerate in which a tooth probably of *Palæosyops* was found leads the writer to conclude that this eruption took place during late Eocene time and that probably some of the larger mountain ranges above mentioned were formed at approximately the same time.

The occurrence of this acidic eruptive rock in the elevated and disturbed region about Carthage indicates that it is probably connected beneath the surface with a much larger laccolithic mass; the intrusion of this mass brought up the older sedimentary deposits, including the coal-bearing rocks, into a faulted dome that has subsequently been truncated down to its present level. It is also probable that the metamorphism resulting from this disturbance improved the quality of the Carthage coal by changing it from a subbituminous to a good grade bituminous coal.

THE COAL.

GENERAL CHARACTER.

The coal from the one workable bed of the field ranks in quality with the best coal of the Southwest. It has a black, shiny luster and contains very little physical impurity. It has well-developed vertical joints, which in certain places seem to bear a definite relation to the faults. One system is parallel to a near-by fault; another plane cuts this at right angles, and yet another at about 60°. This arrangement causes the coal to break down in rough prisms, with faces intersecting at angles of 30°, 60°, and 90°.

The coal is said to produce an excellent coke. During the first period of mining in the Carthage field coke ovens were erected at San Antonio and considerable coke was produced, but when the operations of the mines ceased the ovens were torn away and they have not been rebuilt since mining has been resumed, the operators feeling some doubt as to the quantity of workable coal in the district.

A sample of the Carthage coal was collected in the usual manner by cutting a perpendicular channel across the bed from roof to floor, pulverizing the coal to pass a sieve of ½-inch mesh, thoroughly mixing and quartering it, and rejecting opposite quarters until a quart sample remained. This was sealed air-tight in a galvanized can and sent to the laboratory for analysis.

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[a] See Lee, W. T., Water resources of the Rio Grande valley in New Mexico, and their development: Water-Supply Paper U. S. Geol. Survey No. 188, 1907, p. 17.

Analysis of coal from the Hilton mine, Carthage, N. Mex.

[Laboratory No., 6004. Air-drying loss, 1.40 per cent.]

	As received.	Air dried.	Dry coal.	Pure coal.
Proximate:				
Moisture	3.03	1.64	....	....
Volatile matter	38.03	38.57	39.22	42.45
Fixed carbon	51.56	52.29	53.17	57.55
Ash	7.38	7.50	7.61	....
Ultimate:				
Ash	7.38	7.50	7.61	....
Sulphur	.92	.93	.95	1.04
Hydrogen	5.44	4.27	5.26	5.70
Carbon	73.27	74.30	75.56	81.77
Nitrogen	1.13	1.15	1.17	1.26
Oxygen	11.86	11.85	9.45	10.23
Calorific value:				
Calories	7,369	7,474	7,599	8,224
British thermal units	13,264	13,448	13,678	14,803

The above analysis compares favorably with those of choice coals of southwestern Colorado and northwestern New Mexico.

MINE DESCRIPTIONS.

Government mine.—The Government mine is located in the SW. ¼ NW. ¼ sec. 15, T. 5 S., R. 2 E., New Mexico principal meridian. The main entry takes the full dip of 15° S. 32° E. The coal is 5 feet 6 inches to 6 feet thick and has a massive sandstone roof at places, with a few feet of shale intervening. There has been an attempt to work the mine on the single-entry, room-and-pillar plan, but owing to the faulted condition of the coal bed there is no definite method of underground workings. At one point in the mine a gasoline engine draws coal up the dip from four directions.

Bernal mine.—The Bernal mine has two entries to underground workings, an original slope located in the SW. ¼ NW. ¼ SE. ¼ sec. 15; the other, more recently opened, in the NE. ¼ SE. ¼ SW. ¼ sec. 15. The coal bed is 6 feet thick and has a shale roof. A steam hoist transports the coal from the mine up a slope of 12° to 15° to a tipple. Numerous faults having various degrees of throw and direction of strike are encountered in the workings. The new slope of the Bernal mine was opened under the direction of W. L. Weber in 1904.

Hilton mine.—The Hilton mine is located in the NE. ¼ NE. ¼ sec. 15; the bed is 5 feet thick and has either a sandstone or a shale roof, usually the latter; it has an average dip of about 15° SE. In the underground workings numerous faults have been encountered which strike as a rule in a northeast-southwest direction, with downthrow to the southeast. Just beyond the workings on the southeast there are surface exposures of red beds which have been considered Jurassic and Triassic, forming the upthrown side of an immense fault. They are the variegated beds, however, younger than the coal, and the coal undoubtedly continues beneath them.

Allaire (Emerson) mine.—The Allaire mine, also known as the Emerson mine, is located in the SE. ¼ SW. ¼ sec. 9. The coal bed is about 6 feet thick and has shale roof and floor. The main slope takes the full dip of 10° S. to the point where faults change the degree and direction of dip. A new slope has recently been completed and the pillars have been drawn from the old workings. All available coal is said to have been taken out of the old mine, which was bounded by faults too large to warrant the expense of continuing the workings. The coal is brought to the surface by a steam hoist and hauled by wagons to San Antonio.

Abandoned mines.—There have been numerous prospects, drill holes, and old workings in different portions of the field. Unfortunately the maps of former and abandoned workings have been lost to the present operators. The same is true of numerous drill records, etc., which were considered of no value when mining in the field was discontinued.

In the SW. ¼ SW. ¼ sec. 10 is located the Manilla or McIntyre mine, which was closed in 1905. The workings were on the Carthage bed. In the NW. ¼ sec. 16 there are remains of old abandoned slopes, evidently on the Carthage bed. At other points are signs of prospects in connection with the original period of operations.

COAL EXPOSURES 15 MILES NORTH OF THE FIELD.

In connection with the writer's work in the Carthage field he examined an area of reported coal about 3 miles northwest of J. E. Wayne's ranch, about 15 miles north of Carthage, in T. 3 S., R. 3 E., New Mexico principal meridian. In the NE. ¼ SW. ¼ sec. 8 there is a small prospect on a coal bed showing the following section:

Section of coal bed in SW. ¼ sec. 8, T. 3 S., R. 3 E.

	Ft.	in.
Sandstone.		
Shale, yellowish	10	
Shale, brown	2	
Coal		11
Shale	1	
Coal		8
Shale		11
Coal	1	1
Total coal	2	8

The coal dips 26° W. and is associated with sandstone and shale, which form a hogback traceable northward for about 2 miles to the township line. The coal is apparently of very good quality, but is badly separated by shale partings. It is the writer's opinion that this coal belongs to an isolated, faulted area, detached from a larger field to the south that is covered completely by recent unconformable beds. However, it is possible that there was a period of erosion prior to the deposition of the unconformable beds of sufficient duration to have removed all the coals from the greater part of the Jornada del Muerto.

CONCLUSION.

The Carthage field is an extremely faulted region situated along the northwest boundary of the synclinal basin known as the Jornada del Muerto. Only one workable bed is present. This is of excellent quality and is associated with sandstone and shale which are probably of Montana age. The rocks in general dip to the southeast and east beneath younger beds.

The variegated clay, sandstone, and conglomerate which bound the Carthage field on the south and east have been thought by coal operators to be the Triassic (?) or beds below the coal, which have been brought to the surface by faulting, thus limiting the field on this side. These beds, however, contain a late Tertiary fauna and are known to cover the coal rocks unconformably. These later Tertiary beds and Pleistocene deposits cover a region of great extent eastward over the Jornada del Muerto, and it is quite possible that the coal-bearing rocks continue beneath them at a depth of about 3,000 feet.

It has been thought that the Carthage field is a small area preserved by faults. The writer is of the opinion that it is connected with a much larger area to the east and has been exposed by doming, faulting, and erosion. On account of the presence of the variegated beds overlying and obscuring the lower rocks drilling will be necessary to determine the real extent of the field.

THE COAL FIELD BETWEEN SAN MATEO AND CUBA, NEW MEXICO.

By James H. Gardner.

INTRODUCTION.

The brief report presented here is based largely on the results of a few weeks' field work in the spring of 1908. The accompanying map (Pl. XXII) has been constructed in part from reconnaissance maps of the region made by Schrader in 1905 [a] and by the writer in 1907.[b] Acknowledgments are due to Albert L. Beekly for valuable assistance in the field and in the preparation of the map.

The work of the past season was confined to the area south of latitude 35° 45′, and the value of the present report lies chiefly in the stratigraphic correlations as shown on the map. In 1905 Schrader traced the geologic formation across the region necessarily in a very hurried way. At that time the relation of the coal-bearing formation in the southern part of the district was unknown and the formation was called "upper Montana;" but in the season of 1907 it became evident to the writer that the "upper Montana" of Schrader as mapped in the region of San Mateo was equivalent to the Mesaverde as traced eastward from Gallup. In 1906 Schrader traced the Mesaverde around the east side of the San Juan Basin, or Durango-Gallup coal field, into the district here considered, which forms the southeast corner of that immense region. The Mesaverde was traced along the west foot of the Sierra Nacimiento, entering this field just east of Cuba; thence it was followed southward to a point about 10 miles south of Cuba, where its identity was lost, owing to the complicated structure in the vicinity of San Miguel. Schrader suspected that the Mesaverde followed southward from this point along the Sierra Nacimiento and mapped a bold escarpment leading southwestward to San Mateo as "upper Montana." In 1907 the writer traced the lower part of the Mesaverde eastward from Gallup to San

[a] Schrader, F. C., The Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 285, 1906, p. 243.

[b] Gardner, J. H., The coal field between Gallina and Raton Spring, New Mexico: Bull. U. S. Geol. Survey No. 341, 1909, pp. 335-351.

Mateo and correlated it with the "upper Montana" at this point. During the past season this formation was mapped eastward from San Mateo to Rio Puerco. In the vicinity of San Miguel the lower member crosses the Puerco, makes a swing to the south around a prominent mesa on the east side of the river, thence continues northward, coinciding with the Mesaverde as traced into the region from the north. The accompanying map shows the closing link in the correlation of the Mesaverde, or lowest important coal-bearing formation, as traced eastward from its type locality in Colorado, southward to Cuba, and westward to San Mateo.

The Mesaverde was mapped from Mesa Verde, Colorado, the type locality, to Gallup, New Mexico, in 1906 by M. K. Shaler.[a] The outcrop of this formation is now known to encircle the San Juan Basin. The same is true of the overlying conformable Lewis shale and "Laramie" formation. The conformable beds below the Mesaverde connect on the south and west with formations in adjacent structural basins of the great plateau province.

GEOLOGY.

STRATIGRAPHY AND STRUCTURE.

On Plate XXII are represented in ascending order six formations—Mesaverde, Lewis, "Laramie," Puerco, Torrejon, and Wasatch. The Mesaverde formation and Lewis shale, as well as the Puerco and Torrejon formations, are grouped together in the legend, for the boundaries of the Lewis and the Torrejon have not been mapped. The Mancos shale in this region includes a transition series of sandstones and sandy shales containing local traces of coal; but as no workable Mancos coal beds are known in the field, there has been no attempt to trace this formation in whole or in part.

The Mesaverde formation is coal bearing throughout the district. The formation here is of about the same character as at other localities in the San Juan region, massive brown and tan-colored sandstones alternating with drab shale and coal beds forming its typical elements. Its thickness is about 1,200 feet. The formation, dipping in a general way northward and westward, lies south of the "Laramie" and covers an area which varies in width from 10 miles on the east to about 40 miles on the west side of the district. This area is not a dip slope, as is the region farther west. Arroyo Chico and Arroyo Torreones have removed a great amount of the Mesaverde strata from the south half of the region and have cut away the dip slope which at one time extended northward from Sierra Chivato to Chacra Mesa. Dutton was impressed by the vast amount of erosion which this region had

[a] A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 316, 1906, pp. 376–426.

undergone in recent geologic time. In his report on Mount Taylor and the Zuñi Plateau [a] he considers the chief erosion to have occurred in connection with elevated land and moist climate in the Miocene. Streams then cut nearly to base-level and a later uplift, in Pliocene time, has never been followed by a great amount of erosion, owing to the aridity of climate which has existed until the present day. This idea seems plausible. There has undoubtedly been a period of powerful erosion at some time previous to the Pleistocene and subsequent to the Wasatch (Eocene). As the Miocene seems generally to have been characterized by terrestrial degradation, it is probable that the greater amount of erosion and canyon cutting occurred at that time. The altitude of the Mesaverde area increases toward the north, from 6,200 feet along Arroyo Chico to 7,000 feet on Chacra Mesa. This increase in altitude is gradual and in the same direction as the general dip (3°) of the strata. In passing northward from Arroyo Chico one encounters numerous extremely irregular low escarpments that form a series of steps stratigraphically as well as topographically higher, until he reaches the topmost strata of the Mesaverde at the summit of Chacra Mesa.

The Lewis shale in this region is very irregular in composition and contains a notable amount of thin shaly sandstone and sandy shale. Its thickness varies, but in few places exceeds 200 feet. The Lewis shale occurs along dip slopes of the highest sandstone of the Mesaverde usually covered by a dense growth of chico and sagebrush. The shale can not be closely mapped except by extremely detailed work involving a great amount of time. It seems sufficient to say that the Lewis shale forms a comparatively narrow irregular belt south of the "Laramie" boundary.

The "Laramie" formation contains important coal beds in the vicinity of Raton Spring and farther west, but does not include any large coal beds where it disappears beneath the Puerco formation, 10 miles southwest of Cuba. The Puerco lies unconformably on the "Laramie" and covers all but a few hundred feet of the lower part of the formation, which is elsewhere the coal-bearing portion. The "Laramie" formation is made up of a massive sandstone at the base, with overlying tan-colored and gray sandstones alternating with drab and brownish shales and thin beds of subbituminous coal.

The Puerco formation consists chiefly of variegated shale and soft sandstones. At its base, however, is a massive sandstone member which can be traced with definiteness across the area. The formation varies in thickness from 800 to 900 feet. It completely covers the "Laramie" in the vicinity of Cuba, where it is typically exposed along Puerco River.

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[a] Sixth Ann. Rept. U. S. Geol. Survey, 1885, p. 190.

Unconformably above the Puerco lies the Torrejon formation, in exposures of varying thickness, because of a prominent unconformity at the top as well as at the bottom. In general appearance the Torrejon is similar to the Puerco and was included in the original Puerco of Cope.[a] At the point where Torrejon fossils were collected by the writer the formation can not be over 300 feet thick.

The Wasatch formation consists of variegated shale, conglomerate, and soft sandstone similar in appearance to the Puerco and Torrejon, but containing a smaller percentage of sand. It rests unconformably on lower rocks. North of Cuba the Wasatch rests horizontally against the Sierra Nacimiento, covering the Puerco, which is tilted to perpendicularity. In thickness the Wasatch formation ranges from 1,000 to 1,500 feet. It contains an abundant vertebrate fauna.

VOLCANIC ROCKS.

Seven miles southeast of San Mateo is Mount Taylor, which has been well described by Dutton.[b] This is a volcanic cone that rises to an altitude of 11,390 feet and is surrounded by a lava plateau having a length of 47 miles in a northeast-southwest direction and an extreme width of 23 miles. This plateau is known as the Mount Taylor Mesa. Its northeastern portion is shown on the accompanying map (Pl. XXII). This mesa was formed by a series of lava flows from Mount Taylor and numerous surrounding vents. Within the mesa itself are many volcanic cones; a cluster of these in the central portion forms the group known as Sierra Chivato. In the walls of the mesa are a number of peaks that disclose volcanic necks as well as the lava which flowed from them. Farther out and isolated from the mesa are numerous volcanic plugs, typified by Alesna and Cabezon peaks. These prominent peaks testify to the original extent of the lava plateau and the great amount of erosion subsequent to the eruptions. Across the valley of Puerco River is Prieta Mesa, which was originally connected with Mount Taylor Mesa by lava flows from vents now marked by plugs left standing in the valley between them. Some of these plugs have been eroded below the level of the lava mesas on either side of the valley. These volcanoes and lava flows are not so recent as the lava in the valley of the San Jose west of Mount Taylor. Dutton considered the initial outbreaks to have occurred in the early Miocene epoch. Small dikes are not uncommon, but they do not form prominent features in the topography.

[a] Cope, E. D., Rept. Chief of Engineers, 1875, appendix LL, p. 1012.

[b] Dutton, C. E., Mount Taylor and the Zuñi Plateau: Sixth Ann. Rept. U. S. Geol. Survey, 1885, pp. 164-182.

THE COAL.

COAL-BEARING FORMATIONS.

The coal beds of the region between Cuba and San Mateo are confined to two geologic formations, the Mesaverde and "Laramie."

The Mesaverde constitutes the surface formation over the greater portion of the area and contains the best coal beds. The extreme upper and lower members of the formation bear coal beds of considerable thickness; the beds in the central portion of the formation are thin. The lowest coal beds are concealed beneath the lava flow of Mount Taylor Mesa for a distance of 28 miles northeast from San Mateo toward Cabezon. Coal beds higher in the Mesaverde, but near the base of the formation, outcrop around the north side of the mesa. The coal-bearing rocks near the top of the formation are confined to Chacra Mesa and its continuation northwestward to Pueblo Alto. This mesa passes beyond the limits of the district mapped and is continuous with the upper escarpment of the Mesaverde along the south side of Chaco Canyon to Sulphur Spring. At the latter point the escarpment comes into close proximity with the one formed by lower Mesaverde beds that outcrop along the west side of the basin; the two series of beds continue northward in the Grand Hogback of San Juan River, then swing to a horizontal position and form Mesa Verde itself.

The "Laramie" formation contains coal beds of poor quality in the vicinity of Raton Spring and farther west. The important coal beds disappear 10 miles east of Raton Spring, and the formation conains very thin beds from that point northward to the Colorado state line.

MESAVERDE COAL BEDS.

Locality 1:[a] In sec. 9 of San Mateo Township (T. 13 N., R. 8 W.) the Mesaverde swings around a small mesa. In the west face of this mesa, 100 feet from the top, there is a coal bed 3 feet thick, with carbonaceous shale immediately above and below. The coal bed dips 5° E. It is apparently of fair quality and probably identical with the bed exposed in the next township north.

Locality 2: From the east side of sec. 34, T. 14 N., R. 8 W., the boundary of the Mesaverde encircles the San Mateo anticline and returns to the west side of sec. 35. From this point the boundary passes westward around the mesa in sec. 9 and thence southward to the point of disappearance beneath the lava surrounding Mount Taylor.

[a] Numbers correspond with those used on Plate XXII.

In the central portion of sec. 27 is a coal bed about 20 feet below a massive sandstone 60 to 100 feet thick, which caps the escarpment at that point. This bed shows the following section:

Section of coal bed at locality 2, T. 14 N., R. 8 W.

	Feet.
Sandstone, massive	60–100
Shale	20
Coal	$4\frac{1}{6}$
Shale, sandstone, and thin coal beds	210
Covered.	
	$294–334\frac{1}{6}$

Locality 3: A coal bed was observed in the northwestern portion of sec. 2, T. 14 N., R. 8 W. The section is as follows:

Section of coal bed at locality 3, T. 14 N., R. 8 W.

	Ft.	in.
Shale, sandy	10	
Coal	2	6
Shale		6
Coal	1	8
Shale	4	
Covered.		
	18	8

Locality 4: At locality 4, in T. 15 N., R. 7 W., the following section was obtained in rocks practically horizontal. The coal contains a large amount of resin.

Section of coal bed at locality 4, T. 15 N., R. 7 W.

	Ft.	in.
Sandstone	1	
Shale	2	
Coal	1	3
Shale		1
Coal	2	8
Shale, carbonaceous	12	
	19	

Locality 5: In the southern part of the same township the following section was made:

Section of strata at locality 5, T. 15 N., R. 7 W.

	Ft.	in.
Sandstone, massive	10	
Shale, drab	1	
Shale, carbonaceous; contains fossil leaves		6
Coal	1	
Shale, carbonaceous		6
Shale; contains poor leaves	1	
Shales, covered.		
	14	

Locality 6: A coal bed of fair quality is exposed in the western portion of T. 15 N., R. 6 W., on the Felipe Tafoya grant. The following is the section of the bed, which dips slightly south at this point:

Section of coal bed at locality 6, T. 15 N., R. 6 W.

	Ft.	in.
Shale	3	
Coal, bony		8
Coal	1	10
Shale, covered.		
	5	6

Locality 7: A coal bed, apparently of good quality, as shown by weathered outcrops, is exposed in the eastern part of T. 16 N., R. 6 W., with the following section:

Section of coal bed at locality 7, T. 16 N., R. 6 W.

	Ft.	in.
Shale	10	
Coal	2	6
Shale	4	
Covered.		
	16	6

Locality 8: In the northwest corner of T. 16 N., R. 5 W., a coal bed of medium quality was observed. This bed is in all probability at the same horizon as the section at locality 7 and has the following section:

Section of coal bed at locality 8, T. 16 N., R. 5 W.

	Ft.	in.
Sandstone.		
Shale	10	
Coal	2	6
Shale, covered.		
	12	6

Locality 9: In the southern half of T. 16 N., R. 5 W., a coal bed is exposed at numerous places. At locality 9 the bed attains a thickness of 3 feet 6 inches, with shale above and below. This coal is of fair quality, to judge from its general appearance on weathered exposure. The bed is exposed in numerous small mesas or outliers and probably corresponds with the coal bed of localities 7 and 8, given above.

Locality 10: In the central part of T. 16 N., R. 4 W., a coal bed showing a surface thickness of 4 feet 6 inches is exposed. The coal is apparently of fair quality and free from partings, as shown by the following section:

Section of coal bed at locality 10, T. 16 N., R. 4 W.

	Ft.	in.
Sandstone.		
Shale, sandy	15	
Shale, brown, plastic		6
Coal	4	6
Shale, brown	5	
Shale, sandy	15	
Covered.		
	40	

Locality 11: In the southeast corner of T. 17 N., R. 5 W., the following bed was observed at locality 11:

Section of coal bed at locality 11, T. 17 N., R. 5 W.

	Ft.	in.
Shale.		
Coal	3	2
Shale	8	
Coal		4
Shale.		
	11	6

Locality 12: In the southeastern part of T. 17 N., R. 4 W., the following section was made in rocks dipping 2° N.:

Section of strata at locality 12, T. 17 N., R. 4 W.

	Ft.	in.
Sandstone, massive, brown	3	
Shale, drab	33	
Shale, carbonaceous	10	
Coal	2	3
Shale, drab	2	
Coal	2	3
Shale, drab	5	
Covered.		
	57	6

Locality 13: In the central part of T. 17 N., R. 3 W., the following section was measured:

Section of strata at locality 13, T. 17 N., R. 3 W.

	Ft.	in.
Sandstone	15	
Shale	10	
Coal	3	
Shale, carbonaceous	18	
Coal	1	10
Shale	1	
Sandstone, coarse, gray	10	
	58	10

Locality 14: At locality 14, 8 miles down Rio Puerco from San Miguel, in unsurveyed territory, the following section is exposed:

Section of strata at locality 14, 8 miles below San Miguel.

	Ft.	in.
Shale, drab	12	
Sandstone		8
Coal, poor quality	2	1
Shale, drab	3	
Coal, poor	1	3
Shale, arenaceous	6	
Coal		6

	Ft.	in.
Shale	8	
Coal		3
Shale	2	
Coal	1	
Shale	2	
Sandstone, soft, brown	20	
Shale, drab	2	
Coal	1	
Shales, brownish and buff	22	
Sandstone	10	
Coal		8
Shales, black and brownish	16	
Sandstone, soft, gray	4	
Shale, arenaceous, brown	4	
Coal, fairly good	2	
Sandstone, hard, grayish white	18	
Shale and sandstones	16	
Sandstone, gray, soft	12	
Sandstone, yellowish	35	
Sandstone, thin bedded, gray	75	
Shale, drab	5	
Sandstone, soft gray	5	
Shale, drab, arenaceous	25	
Sandstone, base of Mesaverde	50	
Transition, Mancos beds.		
	361	5

Locality 15: On the Mesaverde outcrop near Senorita a local copper company has put down a shaft to a depth of 20 feet on a coal bed 6 feet thick. This bed dips 70° E. and is associated with rocks in an overturned monocline adjacent to the Sierra Nacimiento. In immediate contact with the coal on either side is brown carbonaceous shale. This shaft is known as the Senorita mine, but up to the present time no coal has been taken out. The shaft was sunk several years ago and at present is partly filled with débris. The coal is reported to have given satisfaction, but its development depended on local copper mines which have been closed.

Locality 16: In the eastern part of T. 18 N., R. 5 W., a workable coal bed is exposed at the end of Chacra Mesa. The following is a section of this bed, in rocks dipping 3° N.

Section of coal bed at locality 16, T. 18 N., R. 5 W.

	Ft.	in.
Sandstone, gray	10	
Shale	1	
Coal	3	2
Shale, brown	20	
	34	2

Locality 17: In the northern part of T. 19 N., R. 8 W., the following section was measured:

Section of coal bed at locality 17, T. 19 N., R. 8 W.

	Ft.	in.
Shale, dark	3	
Coal, bony	1	
Coal	3	1
Shale, brown, carbonaceous	3	1
	10	2

Locality 18: In the southern part of T. 20 N., R. 8 W., the following section was measured:

Section of coal bed at locality 18, T. 20 N., R. 8 W.

	Ft.	in.
Sandstone, massive	50	
Shale, drab	5	
Coal		6
Shale, dark, carbonaceous	4	
Shale, dark	4	
Coal and bone	1	10
Coal	1	11
Coal and bone		3
	67	6

The coal beds of the field under discussion, as well as of the entire San Juan region, are very irregular as to thickness and horizontal extension. The beds are lenticular, and appear at different horizons in different localities. The upper and lower portions of the formation bear the important coal beds, the intervening strata being barren.

The following is a general section of the Mesaverde formation measured from the mouth of Arroyo Torreones, in T. 16 N., R. 4 W., northward to the east end of Chacra Mesa:

Section of Mesaverde formation from Arroyo Torreones to Chacra Mesa.

	Ft.	in.
Sandstone, massive, brown	50	
Sandstone and shale	125	
Shale and some sandstone	120	
Sandstone, massive, brown	25	
Shale, thin streaks of coal	20	
Sandstone, gray	20	
Shale, drab	10	
Sandstone, gray	10	
Shale	125	
Sandstone, brown	3	
Shale, drab	30	
Sandstone, tan-colored	20	
Shale, carbonaceous	16	
Coal	1	6

	Ft.	in.
Shale, carbonaceous	6	
Coal		6
Shale	5	
Sandstone, gray	8	
Shale	3	
Coal	1	
Shale	1	8
Coal	1	2
Shale	4	
Sandstone, massive, gray	10	
Shale, hard	1	
Coal	3	2
Shale, brown	20	
Shale and thin sandstone	50	
Coal	1	8
Shale	10	
Shale and sandstone	200	
Sandstone, massive, nodular	10	
Shale	6	
Sandstone, brown	8	
Shale, drab	6	
Sandstone, massive, brown	12	
Shale	15	
Sandstone, massive	2	6
Shale and thin sandstone	15	
Coal and bone	1	
Shale	3	
Sandstone, massive, brown	10	
Shale and thin sandstone	6	
Sandstone, massive	15	
Shale, thin streaks of coal	50	
Coal	2	9
Shale	10	
Sandstone, brown	3	
Shale, drab	15	
Sandstone, brown, calcareous	2	
Shale	10	
Coal	1	1
Shale and thin sandstone	150	
Coal	3	
Shale and thin sandstone	50	
Sandstone	20	
	1,328	

"LARAMIE" COAL BEDS.

Coal beds in the "Laramie" formation are known in the vicinity of Raton Spring and to the northwest, along the north side of Chaco Canyon. Very little is known of the quality of the "Laramie" coals in this portion of the San Juan Basin. The beds are undeveloped and little prospected on account of their long distance from any railroad. The coal appears to be much like the "Laramie" coal elsewhere in the basin.[a]

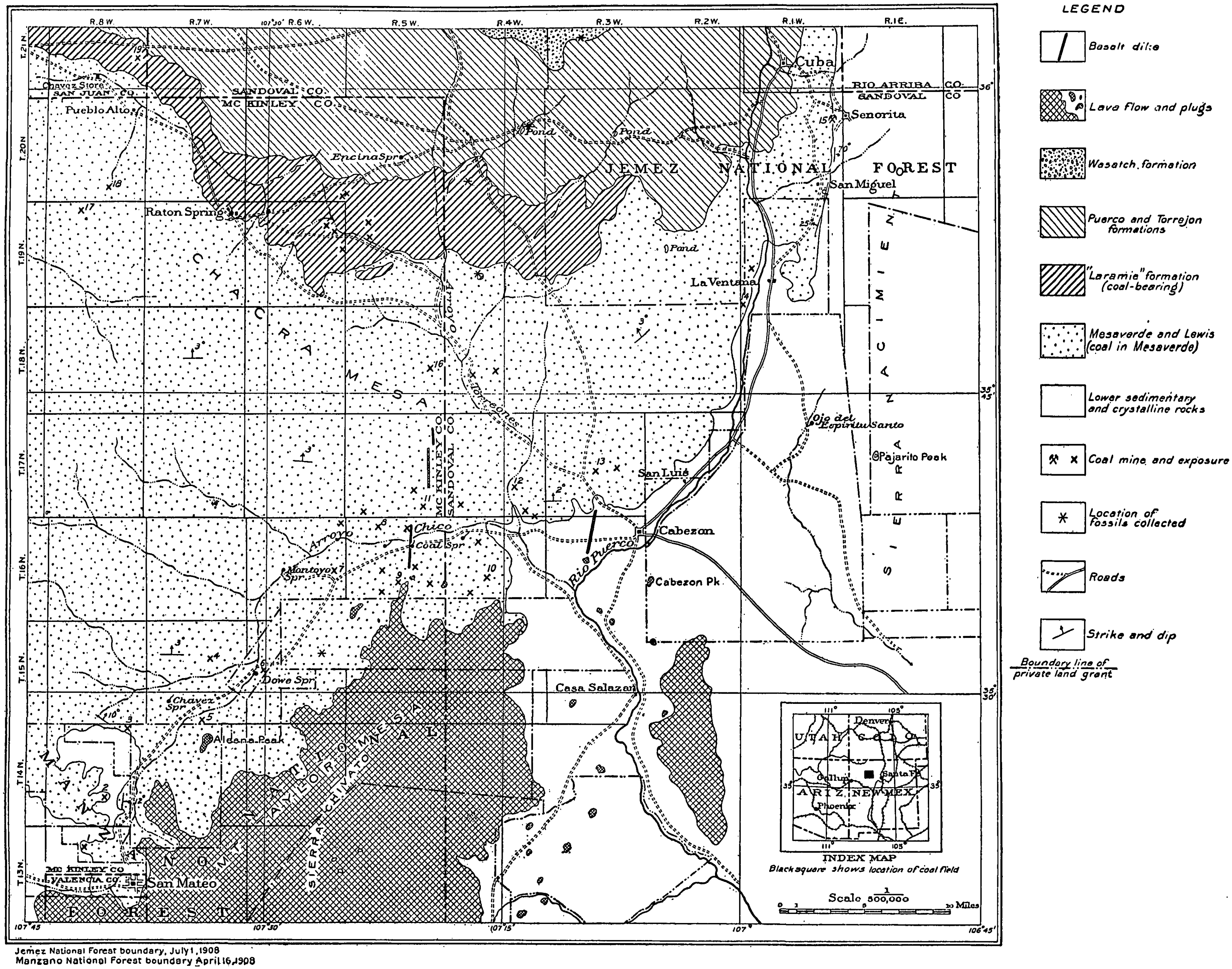
Locality 19: In the eastern part of T. 21 N., R. 8 W., two coal beds were observed in the "Laramie" where the unconformably overlying Puerco shale has been partly removed by erosion. The lower bed is apparently about 7 feet thick and a 5-foot bed is exposed a short distance above it. The character of the "Laramie" strata above and below these beds could not be made out because they are obscured by the Puerco. It is probable that the two beds are identical with the lower and middle of three beds near Raton Spring.

In the northeastern part of T. 19 N., R. 6 W., and the adjacent area there are three coal beds, as shown in the following general section:

Section in Raton Spring and vicinity, T. 19 N., R. 6 W.

	Ft.	in.
Sandstone, gray	3	
Shale, carbonaceous	1	
Coal	2	2
Shale, carbonaceous	3	
Shale, drab	25	
Shale, carbonaceous	1	
Coal		6
Shale		3
Coal	3	7
Shale, dark	3	
Shale, gray, sandy	15	
Sandstone, grayish	3	
Shale, drab	15	
Coal streak		
Shale, carbonaceous	3	
Coal	1	
Shale, sandy		2
Coal	2	
Shale	3	
	84	8

[a] See Schrader, F. C., Bull. U. S. Geol. Survey No. 285, 1906, pp. 241-258, Shaler, M. K., Bull. U. S. Geol. Survey No. 316, 1907, pp. 376-426.



MAP OF COAL FIELD BETWEEN SAN MATEO AND CUBA, NEW MEXICO.

By J. H. Gardner and A. L. Beekly.

QUALITY OF THE COAL.

Little is known of the actual fuel value of the coal in this field. This section of New Mexico is very sparsely populated and at a considerable distance from lines of transportation, so that the coal beds have not been prospected; hence fresh samples were not available for analyses. As the southern part of the field is a district of former volcanic disturbance some metamorphism of the coal is to be expected. A considerable area of coal rocks between San Mateo and the Puerco Valley is concealed by the lava flow forming Mount Taylor Mesa. It is impossible, without drilling, to determine the character of the coal beneath this lava. The immense heat which must have attended these eruptions from Mount Taylor and the surrounding vents probably had some effect on the coal beds now covered by the lava, which at some points reaches a thickness of 200 feet. The lava lies directly on the coal along the truncated boundaries of the inclined beds, but the vertical distance between ranges up to 600 feet at the north edge of the mesa.

The coal of this district is of approximately the same geologic age as that at Gallup. At that place the coal is noncoking and has a fuel value of 10,000 to 12,000 British thermal units on air-dried samples. So far as known to the writer, all the coal of the field discussed in this paper outside of the lava-covered area is similar to the coal of the Gallup district.