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PRINTED: 09-22-2011

ARIZONA DEPARTMENT OF MINES AND MINERAL RESOURCES AZMILS DATA

PRIMARY NAME: DEER CREEK COAL FIELD

ALTERNATE NAMES:
UPPER COAL FIELD

Pinal COUNTY MILS NUMBER: 385

LOCATION: TOWNSHIP 4 S RANGE 18 E SECTION 36 QUARTER W2
LATITUDE: N 33DEG 02MIN 22SEC LONGITUDE: W 110DEG 27MIN 50SEC
TOPO MAP NAME: SAN CARLOS RESERVOIR - 15 MIN

CURRENT STATUS: PAST PRODUCER

COMMODITY:
COAL BITUMINOUS

BIBLIOGRAPHY:
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ADMMR U FILE

DEPARTMENT OF MINERAL RESOURCES

STATE OF ARIZONA

FIELD ENGINEERS REPORT

Mine: Deer Creek Coal Deposit — Date: December 7, 1959

District: Deer Creek, Graham-Pinal Co. — Engineer: Lewis A. Smith

Subject: Report by James H. Thomson, 2201 N. 27th Place, Phoenix, Ariz., to Lewis A. Smith

Mr. Thomson stated that he had leased 640 acres of patented ground to a group from Colorado and Wall Street, New York, on a royalty basis. They now are moving 2 bulldozers into the area to face up the beds. Thus far two seams, 3 feet thick and 3½ feet thick, respectively, have been tested. The coal proved to be a good grade of butuminous. The material was tested at the Universities of California and Colorado. The haul will be 12 miles to the railroad. Mr. Thomson said that the group is reported to have Japanese contracts. They plan to explore the deposit and build a satisfactory road into the area. He said he had several contacts recently with other people.

RE — Bul 225
Int. Economic Geology
(1913)
U.S.G.S.

DEER CREEK COAL FIELDS PINAL & GRAHAM COUNTIES

4-12-57

J. H. (JIM) THOMSON, Phone: BR 5-1885
2201 N. 27th Place
Phoenix, Arizona

Mr. Thomson says he is owner of the Deer Creek Coal Fields.

FPK

From the desk of

FRANK P. KNIGHT

1-19-59

JOHN F. LEWIS **Consultant - marketer**
Smuggler Mine
Aspen, Colorado

called in the office and said he has leased

the Deercreek Coalfield

Pinal & Graham Counties.

See: USGS #225 & 763

DEER CREEK COAL FIELD PINAL & GRAHAM COUNTIES

Went to Deer Creek coal field about 12 miles NE of Winkleman but found no one mining or prospecting for coal. Met a Mr. Barbee, core drill operator, who said he had neither seen nor heard of anyone interested in coal in that area. He has been drilling for Cu for about 3 months near Ash Creek. GW WR 8/27/76

COAL, LIGNITE, AND PEAT.

THE DEER CREEK COAL FIELD, ARIZONA.

By Marius R. Campbell.

INTRODUCTION.

Location.—The Deer Creek coal field of Arizona is an isolated basin of coal-bearing rocks situated in the extreme eastern end of Pinal County. It lies on the south side of Gila River just east of Dudleyville, which is located at the junction of San Pedro and Gila rivers. The field is about 85 miles northeast of Tucson, and at present its nearest railroad point is San Carlos, on the branch road which extends from Bowie, on the Southern Pacific Railway, to Globe, in Gila County. The western end of the field is connected by wagon road with Florence and Tucson and points in the San Pedro Valley. The eastern end is likewise accessible from San Carlos by way of Hawk Canyon, but there are no roads through the field. The coal field is located near the middle of the great copper-producing region of Arizona, which extends from Jerome, on the northwest, to Cananea, Mexico, on the southeast, and includes the great mining centers of Bisbee, Globe, Clifton, and Morenci.

Description.—The region in question lies south of the great Colorado Plateau, and the surface features consist in general of ranges of mountains trending northwest-southeast and separated by undulating valleys, covered for the most part by débris from the adjacent mountain slopes. Along the line of the Southern Pacific Railway these mountain ranges are comparatively narrow, linear ridges, but north of Gila River they show a tendency to coalesce, and the result is a rugged country, of which the Pinal and Superstition mountains are two of the best-known features. The Pinal Mountains proper are limited to the territory north of Gila River, but their southeastern extension is a prominent range which borders the San Simeon plains on the west, and is known by the general name of the Pinaleno Range. Parts of this range, like Santa Teresa Mountains and Mount Turnbull, are

extremely rough and rugged, but in the vicinity of Gila River the range is of only moderate altitude and of simple structure. This

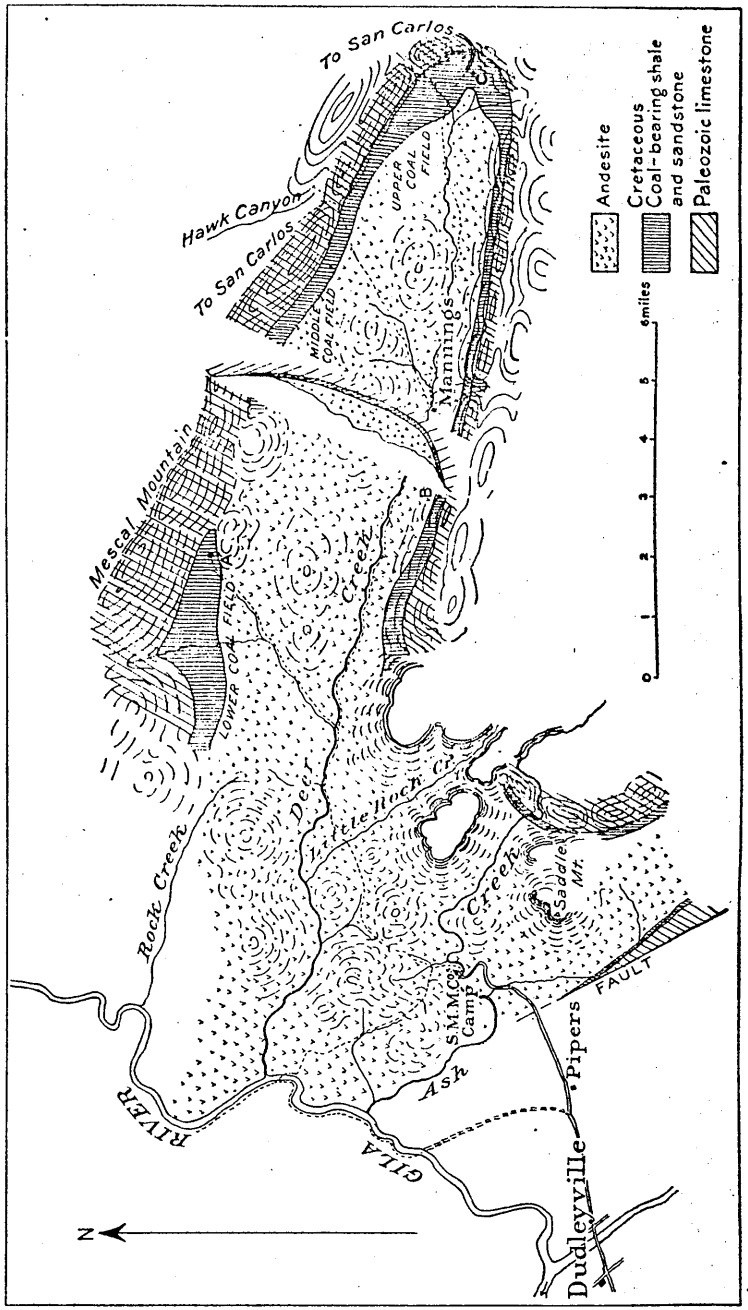

Fig. 7.—Sketch map of the Deer Creek coal field, Arizona.

portion is known locally as Mescal Mountain, and it forms the northeastern limit of the Deer Creek coal field, separating the valley of

Deer Creek, on the west, from that of Hawk Canyon, on the east.

The western border of the coal field is, in a general way, formed by a range of mountains which lies parallel to and east of the San Pedro Valley. South of Aravaypa Creek this range is high, and it is known by the name of the Caliuro Range. Between Aravaypa Creek and Gila River the range is inconspicuous, and it is represented only by a lava-capped mesa just north of Aravaypa Creek and by Saddle Mountain, near Gila River. The topography of the coal field is varied, but, broadly considered, it is a topographic basin surrounded, except on the west, by more rugged country. The basin of Deer Creek is particularly flat in the Upper and Lower coal fields. These are separated by a more rugged region, and between the Lower field and Gila River the topography is rough and mountainous.

The coal field occupies an irregular synclinal basin between the Mescal Range on the north and an unnamed ridge on the south, which separates the basins of Deer and Ash creeks. Within about 5 miles of Gila River the range lying on the south side of the coal field turns to the southwest and merges, in a general way, with the northern extension of the Caliuro Range. The major portion of the coal field is drained by Deer Creek, but the coal-bearing rocks extend to the southwest beyond Saddle Mountain; and this part of the field lies within the drainage basin of Ash Creek. The coal-bearing rocks undoubtedly extend to the northwest beyond Gila River, but they are so broken and disturbed by volcanic rocks that presumably the coal is of no value, and it is not represented on the map.

The field extends 10 or 12 miles in an east-west direction, and it has a known breadth of 3 or 4 miles in the Deer Creek Basin. As previously stated, the coal-bearing rocks are found in the Ash Creek Basin, and it is possible that the coal field may be extended to the outcrop of the limestone west of Saddle Mountain.

Coal beds are also reported as occurring in Hawk Canyon, where the coal-bearing rocks appear on the north side of the great broken anticline forming the Mescal Range, and it seems possible that similar deposits may be found in the basin of upper Ash Creek and in the great Aravaypa Valley to the southeast.

This paper is the result of a rapid reconnaissance of the field during the past autumn. The time was too short to permit of a detailed study of the field relations of all of the rocks involved, but through the kindness of Mr. N. H. Mellor, superintendent of the Saddle Mountain Mining Company, who has given much attention to the geology of the region, the writer was enabled to see many of the critical points and to present the following brief outline of its most important geologic features.

GENERAL GEOLOGY.

Pre-Cambrian schist.—The oldest rocks found within the territory examined are schists, which occur on Ash Creek above the limestone box canyon and on Gila River below the mouth of Ash Creek. No fossils have been found in these schists, consequently their age has not been determined definitely, but undoubted middle Cambrian quartzites and conglomerates rest uncomformably on them, and for that reason they are regarded as being of pre-Cambrian age. Provisionally, these schists are correlated with those described by Ransome from the Globe district to the north, and also from the Bisbee region to the south, and by Lindgren from the Clifton-Morenci region to the northeast. In the Deer Creek Basin the schists were seen at one point only, but it seems probable that they show in most of the anticlines where the movement has been sufficient to bring them to the surface. Along the north side of the basin they were not seen at the head of Hawk Canyon, but to the west they undoubtedly come in within this territory, since they form the main mass of the Pinal Range west of the river.

Cambrian sandstone and shale.—Resting unconformably upon the schists just described, and underlying the great upper Paleozoic limestone, is a series of shale, sandstone, and conglomerate from which fossils were found in the Ash Creek Canyon that Walcott pronounces to be of middle Cambrian age. The sandstone and conglomerate are known locally as "the quartzite," and they have a total thickness of about 850 feet. The closing episode of the Cambrian period seems to have been the deposition of 60 to 80 feet of very fine, green shale, which on Ash Creek appears directly beneath the great limestone mass. Provisionally this is correlated with the green shale of the Grand Canyon region which lies above the Tonto sandstone.

Carboniferous limestone.—Above the green shale just described occurs a great mass of limestone which, in the Ash Creek section, has a thickness of about 1,300 feet. The lower part of this mass is sparingly fossiliferous and no collections were made by which to determine its age. The upper part is richly fossiliferous, and a collection from the uppermost beds outcropping in Ash Creek Canyon indicates that this part at least is of Pennsylvanian age. It is possible that the lower part of the great limestone mass may belong to the Devonian or even the Silurian system, but the evidence at present available would refer most, if not all, to the Carboniferous.

This great limestone mass is the most conspicuous geologic feature of the Deer Creek coal field, since in almost all cases it forms the boundary wall of the basin. Mescal Mountain on the north is composed almost exclusively of beds of this limestone, which, in the cen-

tral part of the basin, must have a thickness of several thousand feet. At the point where it is crossed by the trail from Manning's ranch to San Carlos its thickness is about 1,200 feet. It holds about the same thickness in the small canyon at the extreme upper or eastern end of the field, but in passing to the southern side of the basin the limestone is seen to become thinner and thinner until finally it disappears for a short distance just south of Mount Lou, a little knob in the extreme end of the basin. Whether this disappearance of the limestone is due to faulting or nondeposition was not determined. All along the southern side of the field the limestone is thin and greatly disturbed, and it seems probable that its absence in the eastern end of the basin may be explained by more severe crushing than usual, leaving the coal-bearing rocks in direct contact with the middle Cambrian quartzite.

About 4 miles west of Manning's ranch the small band of limestone shown in the immediate front of the ridge turns to the south and disappears beneath a more recent lava flow that forms a high mesa. At their point of disappearance these rocks strike approximately toward the outcrop of limestone on Ash Creek, and for that reason it has been supposed that they are connected, although concealed by recent flows of lava.

In the basin of Ash Creek the limestone shows in a semicircular line of outcrop just east of Saddle Mountain. The region to the south was not closely examined, but from Mr. Mellor's observations it seems probable that it was forced up by a laccolithic intrusion of volcanic rocks, which now show as a dome-shaped mass directly back of the limestone. If this is truly a laccolith, the limestone beds on its eastern side have been eroded, and since then the whole has been deeply buried beneath extensive flows of lava. In this semicircular line of outcrop the limestone dips away from the center at an angle of about 30°, and to the southwest it seems to form a shallow synclinal trough, which extends southwestward from Saddle Mountain and passes beneath the high mesa lying north of Aravaypa Creek.

The limestone comes again to the surface west of this shallow syncline in a low, anticlinal ridge, which terminates toward the northwest in a fault that cuts out the limestone southwest of Saddle Mountain and south of the road from Dudleyville to the camp of the Saddle Mountain Mining Company. It seems possible, however, that this fault may extend to the northwest beyond the wagon road, and it may have been responsible for the course of Ash Creek below this point.

Fossils were collected from the limestone southwest of Saddle Mountain; in the Ash Creek box canyon; at the point marked "B" on the sketch map, about 1 mile west of Manning's ranch; on the same line of outcrop about 4 miles farther east; and at the head of Hawk Canyon. These fossils have been examined by Dr. G. H. Girty, who pronounces them to be of Pennsylvanian age.

Cretaceous sandstone and shale.—Resting on the Pennsylvanian limestone at every point at which it is exposed in this field is a series of greenish-gray sandstone and shale beds which contain the coal that gives this basin its economic importance. At most points these beds appear to rest conformably upon the Paleozoic limestone, but in the Middle field there is a visible unconformity between the limestone and the overlying sandstone and shale.

Different opinions have been held regarding the age of the coal-bearing beds. Devereux,[a] who reported the field in 1881, noted the occurrence of fossil leaves with the coal, and on the strength of their resemblance to forms with which he was familiar he doubtfully referred the beds to the Tertiary system.

On the basis of their apparent conformity to the limestone below, Blake[b] regarded them as Carboniferous, but probably this conclusion was based upon report and was not the result of an examination in the field.

During the examination made by Walcott[c] in 1885 some fossil plants were collected from the shale associated with the coal beds of the Upper field. These were submitted to Prof. L. F. Ward, who was able to determine the presence of the genera *Sequoia*, *Sabal*, *Phragmites*, *Myrica*, and *Viburnum*. Owing to the fragmentary nature of the material no specific determinations were made, but the formation was doubtfully referred to the Cretaceous. During the present examination similar material was collected from the sandstone overlying the coal in the Lower field and also along the contact between the sandstone and the underlying Carboniferous limestone southwest of Saddle Mountain. This material is so poorly preserved that no specific determinations could be made, but, according to Dr. F. H. Knowlton, one fragment suggested *Sequoia reichenbachi*. The other forms are too indefinite for classification, but they may belong to *Platanus*, *Cinnamomum affine*, or *Asimina eocenica*. The material is so indistinctly preserved that Doctor Knowlton would not venture an opinion as to its age, but the forms given are those which generally are characteristic of the upper Cretaceous. In the Middle field fragments of invertebrates are abundant in a conglomerate bed which is in contact with the Carboniferous limestone. Some were collected and submitted to Dr. T. W. Stanton, who states that they are imperfect specimens of *Ostrea* and *Exogyra*. He states "the latter genus

[a] Devereux, W. B., The Deer Creek coal fields, Arizona: Eng. and Min. Jour., vol. 32, 1881, pp. 404–405.

[b] Blake, W. P., Reports on Mines and Mining: Reports of the governor of Arizona to the Secretary of the Interior for 1896, p. 42; 1898, p. 67; and 1901, p. 108.

[c] Walcott, C. D., and Bannon, M., Deer Creek Coal Field, White Mountain Indian Reservation, Arizona: Senate Ex. Doc., No. 20, 48th Cong., 2 sess., p. 7.

indicates that the age is Cretaceous, but the exact horizon can not be determined from the material in hand."

Although the evidence regarding the age of these beds is not entirely conclusive, there seems to be a general agreement that they belong to the Cretaceous system and presumably were deposited in the later stages of that period. The contact between the Cretaceous rocks and the underlying Carboniferous limestone is usually marked by a thin bed of conglomerate composed principally of fragments of chert derived from the underlying limestone and cemented by oxide of iron.

On the northern side of the Deer Creek Basin the sandstone and shale of the coal-bearing formation have a thickness of 400 to 500 feet. They are well exposed in the Lower field, the material consisting for the most part of coarse, greenish-buff sandstones, which are well exposed and form conspicuous features of the topography. In the Upper field the measures seem to be composed more largely of shale, and they are generally reduced to a comparatively level surface. Walcott[a] states that the thickness of strata exposed below the lower main workable coal bed has a thickness of 2,100 feet, but probably this thickness is due to reduplication of the measures through minor folding, and it is doubtful if the correct thickness can be determined at any point in the Upper field.

On the south side of the basin the coal-bearing rocks appear to be thinner, but it is difficult to obtain an accurate measure since they stand nearly vertical and run for long distances up the slope of the mountain. Still farther west, where they are cut by Ash Creek, the rocks themselves are not exposed, but the interval in which they are due has a thickness of not over 220 feet. Southwest of Saddle Mountain they are still further reduced, having a thickness of 5 to 20 feet between the Carboniferous limestone and the overlying andesite. Whether this variation in thickness is due to different amounts of sediment being deposited on the two sides of the basin, or whether it is due to nondeposition on the western side is uncertain, but it seems probable that the sediments were laid down in inclosed basins, and consequently that the amount of material may have varied greatly in different parts of the area.

After the deposition of the coal-bearing sandstone and shale the region was the scene of great volcanic activity, and large masses of andesite were poured out. There is no crater visible from which this material was ejected, and it seems probable that it came out through extensive fissures which were opened in the lower part of the basin near Gila River. The change from clastic sediments to igneous rocks is not abrupt nor does it appear to have taken place contemporaneously throughout the basin. The sediments are interbedded with volcanic material as though sedimentation was at times interrupted by volcanic outbursts and was resumed when conditions became more favorable. The zone of transition between sedimentary and igneous rocks is marked by a thick bed of coarse conglomerate composed largely of bowlders of granite, Paleozoic limestone, and quartzite. This is a very characteristic bed and can be traced throughout the Territory, except in the upper part of the Deer Creek Basin. Above this bed of conglomerate the andesite has a great thickness, possibly reaching as much as 1,000 feet. In certain parts of the field sedimentation was resumed from time to time, presumably between lava flows, and consequently the lava is interstratified with sandstone beds, and in places even small coal seams appear to have been deposited in these intervals of quiescence.

[a] Deer Creek Coal Field, White Mountain Indian Reservation, Arizona: Senate Ex. Doc. No. 20, 48th Cong., 2d sess., p. 6.

GEOLOGIC STRUCTURE.

The structure of the Deer Creek coal field is comparatively simple, consisting of an unsymmetrical synclinal trough, the axis of which corresponds approximately with the course of Deer Creek near the south side of the basin. South of the creek the rocks are sharply flexed and they stand nearly vertical along the front of the mountain. This great uplift terminates about 3 miles west of Manning's ranch, but the disturbance continues to the west as a small anticlinal fold crossing Deer Creek near the point where the Dudleyville trail first reaches the creek. The fold is of sufficient magnitude to bring to the surface at this point the bed of conglomerate and also some underlying sandstones.

The structure on the north side of the basin is simple; the coal-bearing rocks dip 30° to 60° at the outcrop and then gradually decrease in dip until in the center of the basin they lie approximately horizontal. There have been many minor disturbances generally caused by dikes which cut the strata in all directions. The Upper field in particular seems to be disturbed by many minor structural features, the soft rocks being folded in a number of wrinkles parallel with the general trend of the syncline; on these small folds the coal beds outcrop at many points.

In the Ash Creek Basin the structure is less regular, consisting for the most part of a warped, irregular floor with no definite axes to the depressions. On the whole it seems to constitute a synclinal basin extending northwest and southeast, but in the latter direction it is divided by the great laccolithic uplift on Ash Creek into two shallow basins. The one lying between Ash Creek and Deer Creek is not well exposed, being covered by recent lava flows so as to obscure its structural features. The one west of Ash Creek is marked by Saddle Mountain, which occurs in the center of the depression, but farther southwest the synclinal lifts and only a little of the andesite and coal-bearing rocks now overlies the Carboniferous limestone.

COAL.

The existence of coal in the Deer Creek Basin has been known for at least twenty years, but no commercial development has been undertaken and little information has been published concerning it.

In 1881 Devereux[a] noted the discovery of coal in this field as follows: "Coal was discovered in Deer Creek Valley in the early part of the present year by Anderson and Lillie, two prospectors. As soon as the discovery became known a great deal of excitement ensued, and in a short time the whole valley was staked out into claims."

In 1885 a committee, consisting of Mr. M. Bannon, of Baltimore, Md., and Mr. C. D. Walcott, of the United States Geological Survey, was appointed by the Secretary of the Interior to examine this coal field which then constituted a part of the White Mountain Indian Reservation. The report submitted by this committee[b] gives the history of the discovery of coal as follows:

> The first discovery of the presence of coal in the Deer Creek Valley was made by David Anderson, a prospector, who at the time was seaching for drinking water in a small wash near the head of the valley. A dark band of dirt in the side of the wash attracted his attention and led him to dig into it and ascertain that it was produced by the decomposition of coal. The date of the discovery was the latter part of January, 1881. Anderson notified the members of the prospecting party to which he belonged, and claims were at once staked out along the line of outcrop of the coal-bearing rocks. The work of development was begun soon afterwards, and carried forward as rapidly as the means at hand would permit. Shafts were sunk along the line of the coal seams first discovered by Anderson, and numerous prospect holes dug wherever the coal "blossom" appeared.
>
> In a letter to the Secretary of the Interior, dated Washington, D. C., February 16, 1884, the Hon. H. Price, Indian Commissioner, states that Indian Agent Tiffany, at the San Carlos Agency, notified the miners that they were within the limits of the reservation by posting notices, dated March 4, 1881, on the trails leading to the mines, on the works about the mines, and also had the notice read to passers. This did not deter the prospectors, and the work of development went on until ———, 1883, when they were removed by order of the Department of the Interior by the military under General Crook.

Recently the south line of the reservation has been changed so as to exclude the Deer Creek coal field, and this has caused greater interest to be taken in the development of the field.

At the time of the examination of the above-mentioned committee apparently the Upper or easternmost field was the only one known, and, consequently, their report deals entirely with this region. They describe the coal as follows:

> The strike of the strata in which the coal beds occur averages north 70° west (magnetic); the dip of the coal-bearing bituminous shales and overlying and underlying sandstone is 65° at the surface, increasing to 80° 100 feet below; the latter statement given by the miners. In the tunnel which cuts through two of the best beds thus far opened, the coal appears in the form of thin layers, interbedded with bituminous shale.
>
> The section of the first bed cut by the tunnel gives—

	Ft.	In.
1. Black, bituminous shaly coal, irregular, shining, but not of economic value	3	0
2. Clear bituminous coal	0	10
3. Bituminous shale with parting of coal, similar to No. 2	4	2
Total	8	0

> The second bed is 40 feet beyond, 3½ feet in thickness, with 10 inches of clear coal in one body.
>
> A shaft was sunk on the first bed, and the miners stated that the coal thickens up as they went down, but from the fact that they made no distinction between bituminous shaly matter and the true coal, little reliance can be placed on the statement as proving the existence of a thicker bed of coal. The displacement of the beds during the uplifting of the strata and the intrusion of the dikes of lava has plicated the coal-bearing shales in places and thus given a greater thickness in spots than the beds had originally. * * *
>
> * * * As now known, those beds that present the fairest prospect are limited to a narrow area, about 3 miles long, in the upper part of the valley, on what we have called the Anderson field. That they extend beneath the lava to the westward is quite probable, but to what extent or how much they have been broken up by the numerous dikes and masses of lava that traverse the strata is unknown.
>
> Mr. James Little stated that he knew of at least 40 different seams of bituminous shale and coaly matter between the limestone and the uppermost bed containing coal, a distance of 2,700 feet on the surface and 2,100 feet in thickness of strata. Of those the two seams shown in the tunnel and the first one beyond and above alone appear to be of economic importance.
>
> It may be that when the work of development is carried forward some of the beds not now opened will give thicker beds of workable coal than those exposed by the work done in the Anderson field, but this is uncertain and doubtful.
>
> * * * * * * *
>
> Toward the lower end of the valley, about 10 miles from the Anderson field, the strike swings around to the east and west, and a few exposures of bituminous beds were observed. With the exception of a few prospect holes, no work has been done toward developing this portion of the field.

Since the first exploitation of the Upper field, as noted in the report just given, two other fields have been prospected on the north side of the basin, viz, the Middle and Lower fields. There is no sharp line of division between these, but, in a general way, the Upper field occupies the extreme eastern part of the synclinal basin and may be regarded as lying entirely east of the trail leading from Manning's ranch to San Carlos. The Middle field lies west of this trail and is separated from the Lower field by some lava-capped knobs which seem to cut off the outcrop of the Cretaceous rocks along the north rim of the basin. The Lower field lies west of these knobs and it is bounded on the west by Corral Mesa, a large, intrusive mass near the

[a] Eng. and Min. Jour., vol. 32, 1881, pp. 404-405.

[b] Walcott, C. D., and Bannon, M., Deer Creek Coal Field, White Mountain Indian Reservation Arizona: Senate Ex. Doc. No. 20, 48th Cong., 2d sess., pp. 2-7.

head of Rock Creek, which has completely obliterated the coal-bearing rocks.

The Upper field has received very much more attention than the Middle or Lower fields and a number of slopes have been sunk on the coal beds. Great activity was manifest in this region a few years ago and extensive developments were projected but, owing to the inaccessibility of the field, they were never completed. In the meantime claims have been staked in both the Middle and Lower fields and a number of prospect holes have been dug which show that the coal beds are practically continuous throughout the region.

The writer made a hurried examination of the Upper field and found the coals in much the same condition as described in the report just cited. The development was done so long ago that most of the openings are not now accessible, consequently no new information could be obtained regarding the coal. The beds strike parallel with the main axis of the synclinal trough and dip strongly to the south. Although it is extremely difficult to find continuous exposures, the structure seems to be that of a number of minor folds whose axes are parallel with the main axis of the synclinal trough. The result of such a structure is to expose the same set of coal beds a number of times across the basin; consequently the number of beds actually present has probably been greatly overestimated. As stated in the report previously mentioned, 40 distinct seams of bituminous shale and coaly matter have been reported in a distance of 2,700 feet on the surface, included in a mass of strata 2,100 feet thick. The maximum measure of the coal-bearing shale and sandstone in other parts of the basin is not over 500 feet. Hence it seems highly probable that these 500 feet of sediments have been folded in such a way as to measure 2,100 feet across their outcropping edges.

At one place only in the Upper field was the coal exposed, and at this point the following section was measured:

Section of coal in Upper field.

	Ft.	In.
Coal (good)	0	8½
Coal and shale	2	4
Sandstone	0	3
Carbonaceous shale	0	11
Coal (crushed)	0	9
Total	4	11½

As noted by the commission in 1885, these coals show great crushing, and are in poor condition for commercial mining.

The writer saw no coal outcrops in the Middle field, but a number of openings are reported. It seems altogether probable that the same beds are present in this field as shown in the Upper field, and also as were seen at the Reed shaft in the Lower field.

The Lower field has not received much attention, but lately several shafts and slopes have been sunk, which give a fairly good idea of the number and thickness of the coal beds. The oldest work of this kind is a slope 150 feet long, sunk on a coal bed that shows on the north side of the basin, near the old Indian trail from Dudleyville to San Carlos, which crosses Mescal Mountain near the triangulation station. Recently a shaft has been sunk in the next ravine south of the slope, and presumably the same bed of coal has been cut. The shaft section is as follows:

Section of Reed shaft.

		Ft.	In.
Sandstone, coarse		100	0
Shale		37	0
Coal	1. Coal, hard (including lenses of shale 0 to 3½ inches thick) — 1 foot, 3 inches 2. Coal, crushed — 1 foot, 2 inches 3. Coal, or carbonaceous shale, crushed — 6 inches	2	11
Shale		20	0
Total		159	11

The shaft was extended 20 feet below the coal bed in search of other coals, but nothing was found. It was the intention of the prospector to sink to the limestone, but, owing to the great depth and difficulty of hoisting the material by hand, the work was abandoned at a depth of 160 feet. This shaft is 420 feet south of the Reed slope and is generally known as the Reed shaft. In the slope the coal is considerably disturbed by faulting and minor folding, so that it varies in thickness from point to point. The following sections were measured where the coal is undisturbed, and consequently represent its true structure and thickness. About 75 feet from the mouth of the slope the coal has the following section:

Section of coal 75 feet from mouth of Reed slope.

	Ft.	In.
Coal, crushed	0	3
Bone	0	3
Coal:		
Hard, good	1	0
Badly crushed	1	7
Total	3	1

About 150 feet from the mouth of the slope the coal shows the following section:

Section of coal 150 feet from mouth of Reed slope.

	Ft.	In.
Coal, crushed	0	4
Bone	0	1
Coal:		
Hard, good	0	10
Crushed	0	10
Total	2	1

On the south side of the basin, about 1 mile west of Manning's ranch, a shaft, which shows three coal beds, has been sunk well up on the mountain side. This is known as Crowe's shaft, and has the following general section:

Section of Crowe shaft.

			Ft.	In.
Shale and sandstone			50	0
Coal	1. Coaly shale	2 inches	1	7
	2. Sandy parting	2 inches		
	3. Coaly shale	4 inches		
	4. Sandy parting	3 inches		
	5. Coal, very hard	8 inches		
Sandstone and shale			30	0
Coal	1. Carbonaceous shale	6 inches	1	11
	2. Sandstone	3 inches		
	3. Coaly shale	14 inches		
Shale			15	0
Sandstone			2	0
Shale			3	0
Coal	1. Carbonaceous shale	6 inches	2	0½
	2. Coal	18½ inches		
Carbonaceous shale			0	0
Total			105	6½

The highest coal bed in this section is badly crushed and faulted at the point where it is cut by the shaft, and it is doubtful whether the section given above represents its true thickness and structure. The lowest bed shows considerable crushing, but the section given above is about normal.

The correlation of the coal beds found in the Crowe shaft and the coal of the Reed mine is somewhat difficult. This shaft was not sunk through the Cretaceous rocks, but it seems probable that the lowest bed of coal occurs within 10 feet of the top of the limestone, which is well exposed in a near-by ravine. If that be true, the uppermost bed of coal occurs about 60 feet above the limestone. This is nearly the position in which the coal is found in the Reed shaft. It is at least 30 feet above the limestone, and may be as much as 40 or 50 feet. The exposures in the vicinity of the Reed slope are not very satisfactory, but some indications of coal smut were seen near the top of the limestone in the ravine west of the slope, which seems as though it might correspond with the bottom bed in the Crowe shaft. Since the writer visited the field, according to Mr. Mellor, prospecting has been done, for the purpose of determining whether a lower bed is present near the Reed slope, but nothing was found. It seems probable, however, that the coal of the Reed shaft and slope is about equivalent to the highest bed in the Crowe shaft, and that the smut seen near the limestone at the Reed mine is at about the same horizon as the lowest bed in the Crowe shaft.

Mr. Mellor recently has discovered traces of a coal bed near the

top of the Reed shaft, but this does not seem to correspond to any of the beds showing in the Crowe shaft, and it is not known whether it has any representation on the south side of the basin.

Although sufficient prospecting has not been done to determine clearly the number of workable coals in the basin, it seems probable that they are limited to two beds, and the occurrence of similar exposures on the two sides of the field is fairly good evidence that the beds extend entirely across the Deer Creek Basin.

The most favorable locality for developing these coals is where the geologic structure is the simplest, and also where the coals are the least disturbed by dikes and other intrusive masses of rock, and also where they can be most easily reached by a railroad from Gila River. So far as could be determined in the hasty examination just made, the Lower and Middle fields appear to be less disturbed by complicated folding than the Upper field, consequently the coal is better disposed for economical mining. The coals in the Upper field make a larger showing at the surface, but, according to the present interpretation, this is due to minor folds, and these would be extremely troublesome in commercial mining.

All parts of the field are much disturbed by igneous dikes and the three fields in question have suffered about equally in this respect.

With regard to transportation facilities the Lower field has a decided advantage, since the surface of the basin in this field is comparatively flat and not diversified by any marked hills or sharp and deeply cut valleys. It is also considerably nearer Gila River and could be much more easily reached by a line of railroad than could either the Middle or the Upper field.

The Lower field is divided into two parts by an extensive dike which trends nearly east and west, and presumably extended from an igneo outflow in the knobs east of the Reed mine. Along this dike there has been considerable disturbance of the adjacent rocks, and this region should be avoided in the development of the field. There is, however, a large area to the north of this dike in which the coal can probably be found within a distance of 100 to 200 feet of the surface and in which the rocks are comparatively undisturbed. Also the region south of the dike in the center of the basin offers promising territory for the development of mines. Only two small dikes were observed between the large dike just mentioned and Deer Creek. These dikes are of small dimensions and probably do not extend for a very great distance. With the present information it is impossible to say at what depth the coal occurs below the surface in the center of the basin, but it seems probable that nowhere does it exceed 600 to 700 feet.

QUALITY OF COAL.

Owing to the large amount of impurities in this coal it is of a comparatively low grade, and if the field were more favorably located

the coal would have little or no commercial value, but as the field is situated in one of the most arid portions of the country, in the center of a great copper-producing territory, and in a region which is comparatively rich in gold and silver, the coal may have a local value considerably beyond that which is indicated by its chemical analysis.

In a general way the coal of the Lower field, as seen by the writer, and of the Upper field, as reported by the commission which examined it in 1885, occurs in two benches, in which the coal differs considerably in quality. The first and best grade usually is contained in small benches from 10 to 15 inches in thickness. This is an extremely hard, block coal, and has been little affected by the movements that have upturned the rocks. The other benches are composed of very much softer coal, presumably at first containing much more foreign material. In the movement which has folded the rocks of the basin this softer bench has suffered great crushing, and at all points where it is accessible the coal is crushed into thin laminæ, which show much slickensiding where the particles have crushed together. Doubtless the hard block coal would find a ready market at any of the towns or mines in the vicinity, and, according to laboratory tests, it can be manufactured into coke. The softer coal is so badly crushed that it could be put on the market only as slack, and, as it carries a heavy percentage of ash, presumably it could not profitably be shipped a long distance.

The coal of the upper field was sampled by the commission,[a] and, as analyzed by Mr. Edward Whitfield, of the United States Geological Survey, shows the following percentages:

Analysis of coal from 10-inch layer in bed opened by tunnel in Upper field.

	Per cent.
Moisture	0.48
Volatile combustible matter	19.81
Combined carbon	61.01
Ash, pink in color	18.70
Coke	Poor.

Analysis of coal from 10-inch layer in bed reached by crosscut from tunnel in Upper field.

	Per cent.
Moisture	0.56
Volatile combustible matter	17.50
Combined carbon	60.85
Ash, pink in color	21.09
Coke	Fair.

The commission also reports "the coal is a hard bituminous, and, as tested in the laboratory, will make a fair coke, but not so good as that from the Raton district of New Mexico."

[a] Deer Creek Coal Field, White Mountain Indian Reservation, Arizona: Senate Ex. Doc. No. 20, 48th Cong., 2d sess., p. 3.

The coal beds of the Lower field were carefully sampled by the writer, but the results do not show so good a coal as that shown by the analyses just given. Whether this difference is due to the mode of sampling or whether it is on account of the better quality of the coals in the Upper field can not now be decided. In order to test the coal of the Lower field, a cut was made in the Reed shaft across the bench of hard coal, 15 inches thick (No. 1 in the section on page 251), which, according to Mr. Eugene C. Sullivan, of the United States Geological Survey, shows the following composition:

Analysis of hard coal from Reed shaft, Lower field.

	Per cent.
Moisture	1.22
Volatile combustible matter	28.80
Ash, almost white	43.74
Fixed carbon	26.24
Sulphur	1.69
Silica in ash	48.3
Coke	Dull, not swollen, coherent.

In this field the softer parts of the bed seem to have value, consequently a sample was obtained from the lower bench, 20 inches in thickness, including Nos. 2 and 3 in the section given on page 251. According to the same authority the analysis of this crushed portion is as follows:

Analysis of bottom part of crushed coal from Reed shaft, Lower field.

	Per cent.
Moisture	2.98
Volatile combustible matter	23.07
Ash, slightly pink	53.01
Fixed carbon	20.94
Sulphur	1.26
Silica in ash	61.6
Coke	Dull, not swollen, friable.

Of the crushed portion of the bed the upper part, having a thickness of about 14 inches, seemed to be of better quality than the lower, and a sample, according to the same authority, shows the following composition:

Analysis of upper part of crushed coal from Reed shaft, Lower field.

	Per cent.
Moisture	2.60
Volatile combustible matter	23.41
Ash, white	54.43
Fixed carbon	19.56
Sulphur	1.98
Silica in ash	53.4

Noncoking.

In the Crowe shaft a sample was obtained by making a cut across the lower bench of coal 18½ inches in thickness. This was analyzed by Mr. Sullivan with the following result:

Analysis of lowest coal in Crowe shaft, Lower field.

	Per cent.
Moisture	1.76
Volatile combustible matter	36.65
Ash, light reddish	34.78
Fixed carbon	26.81
Sulphur	1.91
Silica in ash	51.5
Coke	Dull, not swollen, friable.

The striking feature of the above analyses is the high percentage of ash, which in the samples taken runs from 34 to 54 per cent. At first this heavy percentage seems to be prohibitive, but when it is considered that much of the Colorado and New Mexico coal delivered in this region probably does not run under 17 per cent of ash, and some of it exceeds this figure, it is apparent that local coal, even with the heavy percentage shown in the above analyses, may be able to stand in competition. It is possible that the ash may be reduced by washing, if the coal is transported to Gila River, where sufficient water is available for this purpose. The hard bench of the coal, however, has a rather high specific gravity, so that the separation of the coal and shale would not be an easy matter.

One of the greatest demands for fuel in this country is for coke to supply the copper smelters. In the early days this was brought from abroad at a cost of from $50 to $75 per ton, but recently with increased railroad facilities the region is supplied with Colorado and eastern coke at a cost of from $10 to $15 per ton. The commercial value of the Deer Creek coal depends largely on whether it will produce a coke that can be used in the copper smelters and that can be supplied at a cost below that obtained for eastern coke.

As will be seen from the analyses, almost all the coals of this field will produce coke, but as tested in the laboratory the upper bed, or that shown in the Reed shaft, is the most promising. This bench of coal has a thickness of about 15 inches. The lower bed, as sampled in Crowe's shaft, yields an inferior coke, so that probably it can not be depended on unless it is found in actual practice that the coke is of better quality than that produced in the crucible. Generally it is recognized that all laboratory tests of coking coals are inadequate; therefore it is desirable in all cases to make practical tests in the field before beginning operations.

During the process of coking in the ordinary beehive oven the volatile, combustible matter is driven off and also a considerable percentage of the fixed carbon is burned up. Owing to this reduction in the percentage of the fuel part of the coal, the percentage of ash in the

coke is increased considerably above that which appears in the coal, so that instead of having to deal with 40 to 43 per cent of ash it is probable that the coke will contain at least 50 per cent, and possibly it may run to a greater figure.

The use of such impure coke in the copper smelters depends largely upon the amount of silica contained in the ash. The ores are generally basic, and there is a tendency for them to combine with the siliceous lining of the furnace. It seems probable that in case the coke contains a heavy percentage of silica this may combine with the basic ores, thus relieving the siliceous lining of the furnace to a considerable extent. In order to determine this, tests were made of the percentage of the silica in the ash, and as shown in the accompanying analyses it runs about 50 per cent.

As previously stated, it is possible that this percentage of ash may be reduced by washing, but this would necessitate the erection of a costly washer plant at the river, and the gain may not be sufficient to warrant the expenditure. It is recommended, however, in case these coals are mined and coked to experiment with washing and see if the percentage of foreign matter may not materially be reduced.

RÉSUMÉ.

From the foregoing facts regarding the coal of the Deer Creek Basin it seems safe to assume that there are two beds of workable thickness throughout the larger part of this basin. The dimensions of the field are approximately 3 by 10 miles; its area is about 30 square miles. The beds are thin, but from the measurements obtained it seems probable that they range from 24 to 30 inches in thickness, and this is within the limits of a workable coal. The tonnage of the field, based upon an estimate of 24 inches of coal throughout a basin 3 by 10 miles in extent, is about 60,000,000 tons. About 50 per cent of this may be available, making 30,050,000 tons of coal.

The coal is fairly well disposed for mining, except where it is subject to local disturbances and where it has been cut by igneous dikes. These disturbances are generally apparent at the surface and may be avoided in the location of commercial mines.

In a general way the coal is of two qualities, the first being a hard, block coal, which is fairly well adapted for transportation and for commercial use, and also may be manufactured into coke. The second grade is a soft, badly crushed coal, which carries a heavy percentage of ash, and which, owing to its peculiar condition, probably can not be marketed. It carries, however, a fairly large percentage of volatile matter, and it may be utilized in one or two ways, either by being manufactured into gas and the gas piped to the place of consumption, or to generate electricity in the field and the power carried by wire to the place where it is needed. By the latter method only a small per-

centage of the fuel value of the coal would be utilized; therefore it seems probable that the former method would be the most economical means of using this deposit. By the modern methods of making producer or water gas the whole of the fuel value of this coal might be utilized.

The facts so far presented are those which concern the geologic occurrence of the coal, and these alone are of interest in the present connection. The development of the field and the best mode of utilizing the fuel is a question which concerns the engineer and should be approached only by one who is thoroughly familiar, not only with local conditions, but also with the best method of handling fuels of this character.

See: ABM Bull. 180, p. 59, 65, 68, 69
USGS Bull. 225