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HENRY LANDES, State Geologist

BULLETIN No. 10

The Coal Fields of Pierce County

By JOSEPH DANIELS

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LETTER OF TRANSMITTAL.

Governor Ernest Lister, Chairman, and Members of the Board of Geological Survey.

GENTLEMEN: I have the honor to submit herewith a report entitled "The Coal Fields of Pierce County," by Joseph Daniels, with the recommendation that it be printed as Bulletin No. 10 of the Survey reports.

Very respectfully,
HENRY LANDES,
State Geologist.

University Station, Seattle, September 1st, 1914.

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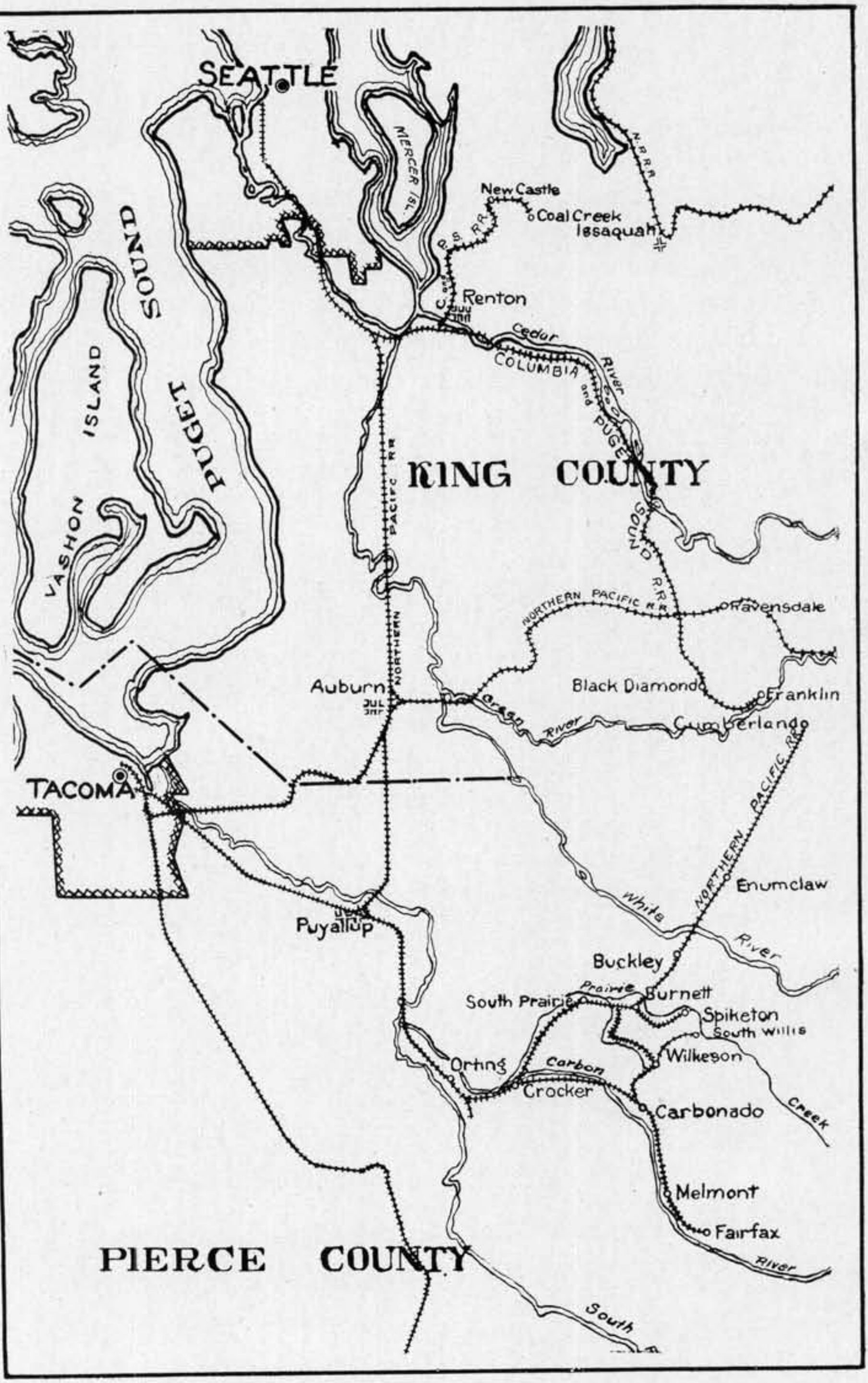
LOCATION AND EXTENT OF THE COAL FIELDS.

Pierce County is situated in the western part of Washington on the west slope of the Cascade Mountains, extending from the summit line, longitude 121° 20′ West, to the shores of Puget Sound, longitude 122° 45′ West. On the north the boundary mainly follows the White River from its headwaters near Natchez Pass; on the south the Nisqually River marks the greater extent of the boundary. The north-south extent is embraced between parallels 46° 45′ and 47° 20′. Tacoma, on the shore of Admiralty Inlet, is its largest city and county seat.

The coal fields occupy a relatively small portion of the areal extent of the county. They extend in a north-south belt on either side of meridian 122°, including Townships 15 to 19 North and Ranges 6 and 7 East, Willamette Meridian, embracing perhaps 100 square miles in area. [Plate I.] The productive portion of this belt, the drainage areas of Carbon River and its tributaries, South Prairie Creek, Gale Creek and Evans Creek, occupies 25 square miles in the northern half of the field. This northern portion has long been known as the Wilkeson-Carbonado field and the name will be retained in the present bulletin, the term including the mines at Melmont and Fairfax. The southern portions of the Pierce County coal area have been variously designated as the Puyallup, Narrow Gauge, Busy Brook, and Ashford fields. In this bulletin it will be collectively known as the Puyallup-Ashford field. It is probably true that the north and south fields are continuous across the concealed areas tributary to the Puyallup River, but the separation into the two fields is made because of present economic conditions.

The northern field is reached from Seattle or Tacoma by the Northern Pacific Railway, Buckley Branch, from Puyallup. [Plate II.] This was formerly the main line of the railway across the Cascades. From South Prairie a branch road extends to each of the mining towns of Spiketon, Burnett, Wilke-



Place Map Showing Mining Towns.

son, Carbonado, Melmont and Fairfax. A branch line from Crocker extends up the Carbon River to Wingate, the shipping point for the Carbonado mines. Fairfax is 52 miles from Seattle and 38 miles from Tacoma. The southern field has no transportation facilities at present except at Ashford. Ashford is the southern terminus of the Tacoma Eastern Railroad which is a branch of the Chicago, Milwaukee and Puget Sound main line running out of Tacoma, tapping a valuable timber country, and forming an entranceway to the Mount Rainier National Park.

PURPOSE OF INVESTIGATION.

The purpose of this investigation is to record the location and extent of the coal-bearing formation, the structure of the field, the correlation of the seams, the methods of mining and preparation of the coal, and the manufacture of coke. The most important part of the present study is the analysis of the northern field for the purpose of determining the extent and structure, beyond the limits of the present workings, of the seams now being worked. In this way it is hoped to throw some light on the complex structure of this important field and give such data to the operators as will enable them to plan more intelligently the future development of the district.

CHARACTER AND METHODS OF WORK.

The surveys made by the Northern Pacific Railway engineers in locating their line across the Cascades and from Portland to Tacoma took into account the presence of coal in Pierce County. The earliest data, therefore, was that obtained by engineers sent out by the railway before 1870.

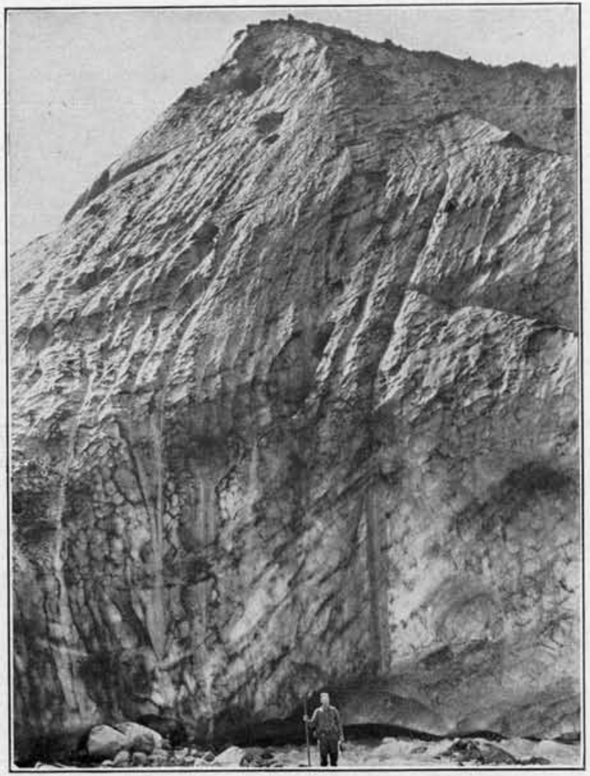
After this came the Northern Transcontinental Survey, made by the U. S. Geological Survey in 1881-1884. Careful attention was given to the geological relationships of the coal fields of Washington and the summary of the results of this survey were reported in the Tenth Census of the United States, 1880, Vol. XV, 1886, pp. 759-771, in a paper entitled "Report on the Coal Fields of Washington Territory," by Bailey Willis.

This was the first of a series of contributions by this geologist, whose work, done under the limitations of time and scant data, has been the basis of the economic development of several of Washington's coal areas. Further work by Bailey Willis in 1896 led to the publication of "Some Coal Fields of Puget Sound (Wash.)" in the Eighteenth Annual Report, U. S. Geological Survey, Pt. III, 1897, pp. 393-436. This report contained two plates dealing particularly with the topography, mine workings, and structure of the Wilkeson-Carbonado field. Following this there was published the Tacoma Folio (No. 54), Geological Atlas of the United States, U. S. Geological Survey, 1899, in which all the known facts of the Wilkeson-Carbonado field were brought down to that date. In an article on "The Coal Fields of the Pacific Coast," in the Twenty-second Annual Report, U. S. Geological Survey, Part III, 1901, pp. 473-513, George Otis Smith gives a review of the structure of this field and considerable data on the economic development. Finally in 1909-1910, E. Eggleston Smith, of the U. S. Geological Survey, examined and sampled the coals of the entire state in co-operative work carried on with the Geological Survey of Washington. The results of the sampling and analyses are published in "Coals of the State of Washington," by E. Eggleston Smith, Bulletin U. S. Geological Survey, No. 474, 1911, pp. 167-193. This material has been freely used in compiling the present bulletin.

Summary reports dealing with the Pierce County coal areas were published in the Annual Reports of the Washington Geological Survey for 1901 and 1902. In 1910 work was commenced on a base map of Pierce County and in 1911 a survey was begun under the direction of George W. Evans. Sections along Carbon River, Evans Creek, on the Narrow Gauge and on the Busy Brook were measured, but this material was never satisfactorily worked up. Changes in the personnel of the assisting force and the resignation of Mr. Evans from the Survey hindered and delayed the work and resulted in a heterogeneous mass of data being bequeathed to the writer of the present report. The field season of 1913 was spent by the writer in the Wilkeson-Carbonado area, studying mainly the underground relationships and structure of the field as developed in the mine workings, measuring rock tunnels and coal sections, investigating the methods of mining and preparing the coal for market, and the coking industry. All of the operating mines of the northern half of the field were examined, but no attempt was made to visit any of the prospects or areas in the Puyallup-Ashford area.

The difficulties in tying together and reconciling the fragmentary data of the earlier surveys with his own work have been many, and the writer makes this statement in order to explain any discrepancies or errors which may be found in this bulletin. The mining companies and officials have been uniformly courteous in willingly furnishing available data for the use of the Survey in compiling this report. Acknowledgment is here graciously recorded to all who have assisted the writer in his work.

One fact stands out very prominently, viz.: the large amount of data which is forever lost to the mining companies and to investigators by the failure and apparent lack of appreciation of value on the part of the operating officials of the structural facts involved in changes in the thickness and character of the coal beds, the rolls, slips and faults, etc. These are but passing problems and are quickly forgotten, but they are often of great value in the solution of new and future problems arising in the working of so complicated a field as the Pierce County area. With only meagre data available from the surface geology, future problems can only be solved by a knowledge of the underground structure developed in old workings. Such data should be accurately recorded on the maps at the time the facts develop and before the places are worked out and closed or timbered and nothing but a hazy memory or recollection remains. Thousands of dollars can be saved to the companies if they will record these facts in time.



A. Nose of Carbon Glacier.

B. Debris on Carbon Glacier.

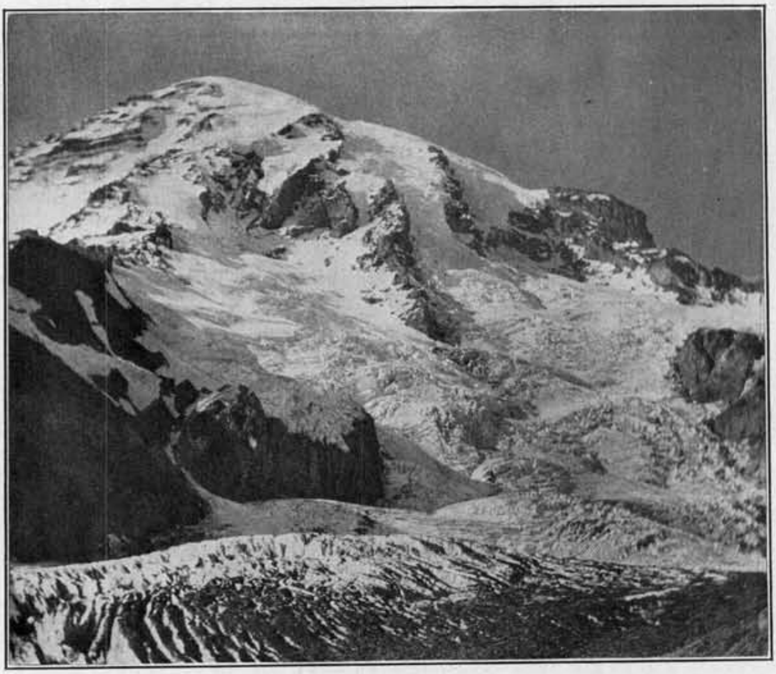
CHAPTER I.

SURFACE FEATURES.

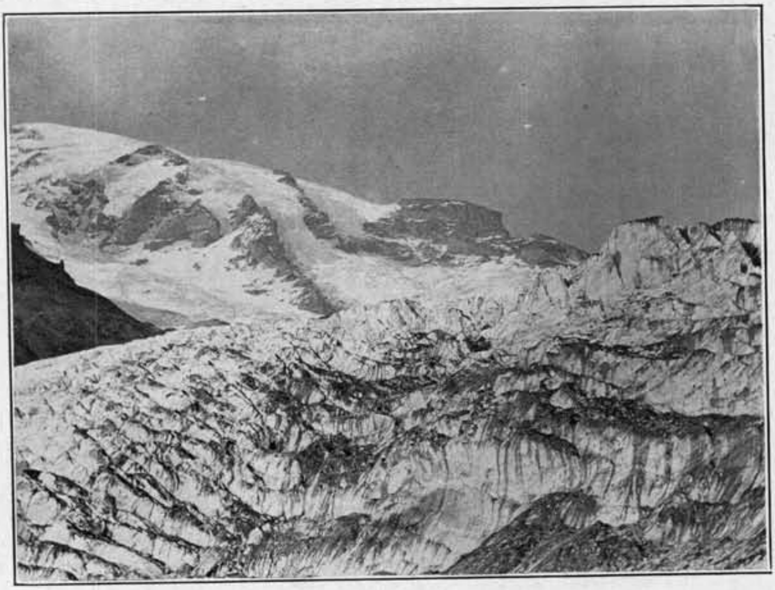
TOPOGRAPHY.

Elevations in Pierce County range from 14,408 feet, the height of Mount Rainier, which occupies the southeastern portion of the county, to sea level on the shores of Puget Sound. Mount Rainier stands out as an isolated peak west of the main range of the Cascades. The crest of the range, at an average elevation of 6,000 feet, forms the boundary line between Pierce and Yakima counties. On the north and west sides of Mount Rainier the foothills extend to the gravel terraces which, on the west, make up the plateau bordering the Puyallup River, and extend on the north to the gravel covered hills along the White River. On the west, north of the Nisqually River, the country is much more rugged and mountainous directly adjoining the slopes of Mount Rainier, but this topography gives way to the southward extending gravel plateaus noted above. These foothills, in places showing igneous outcrops, mark the range of elevations between 6,000 feet and 2,500 or 3,000 feet. At the lower elevation occasional outcrops of the coal bearing formation are found, but in the main everything is concealed under the Pleistocene gravels which form the hills and terraces down to the plateau level which here is about 500 feet. Thus within the limit of the coal areas we may distinguish three topographic features; first, the igneous foothills of Mount Rainier at elevations of 2,500 to 6,000 feet; second, the hills and terraces of drift under which the coal measures lie, with elevations ranging from 2,500 to 500 feet; third, the gravel plateaus which make up the prairies.

The highest elevation at which drift has been found is about 1,700 feet, and its depth over bedrock varies from a few feet to three or four hundred feet. Timber and air-chutes from the upper limits of mine workings to the surface reveal these ranging depths of cover. This great mantle or accumulation of



A. Mount Rainier and Nisqually Glacier.



B. Nisqually Glacier.

drift, together with the heavy forest growth characteristic of the Puget Sound country, have well nigh hidden the underlying rocks, and only here and there on the creeks and rivers are sections exposed which can be used in working out the structure. Most of the correlation of seams and determination of structure have been made possible by data gathered from mine workings.

The present surface topography, therefore, is not the topography of the rock surface of the coal measures. Below the maximum elevation of drift, 1,700 feet, there is a marked difference between the surface and the pre-glacial topography. The pre-glacial surface has not been determined. Wherever mine chambers, air or timber chutes, shafts or other openings have been driven from coal to surface some data can be obtained. Gravel channels in the coal at Burnett, Gale Creek, and Wilkeson indicate erosion of the seams by pre-glacial or glacial streams. All of this information could be made valuable in an investigation of this sort, but such study has not been attempted for this bulletin. There is little doubt that the folding of the coal measures and erosion took place before the drift was deposited. The evidence along this line will be presented later.

DRAINAGE.

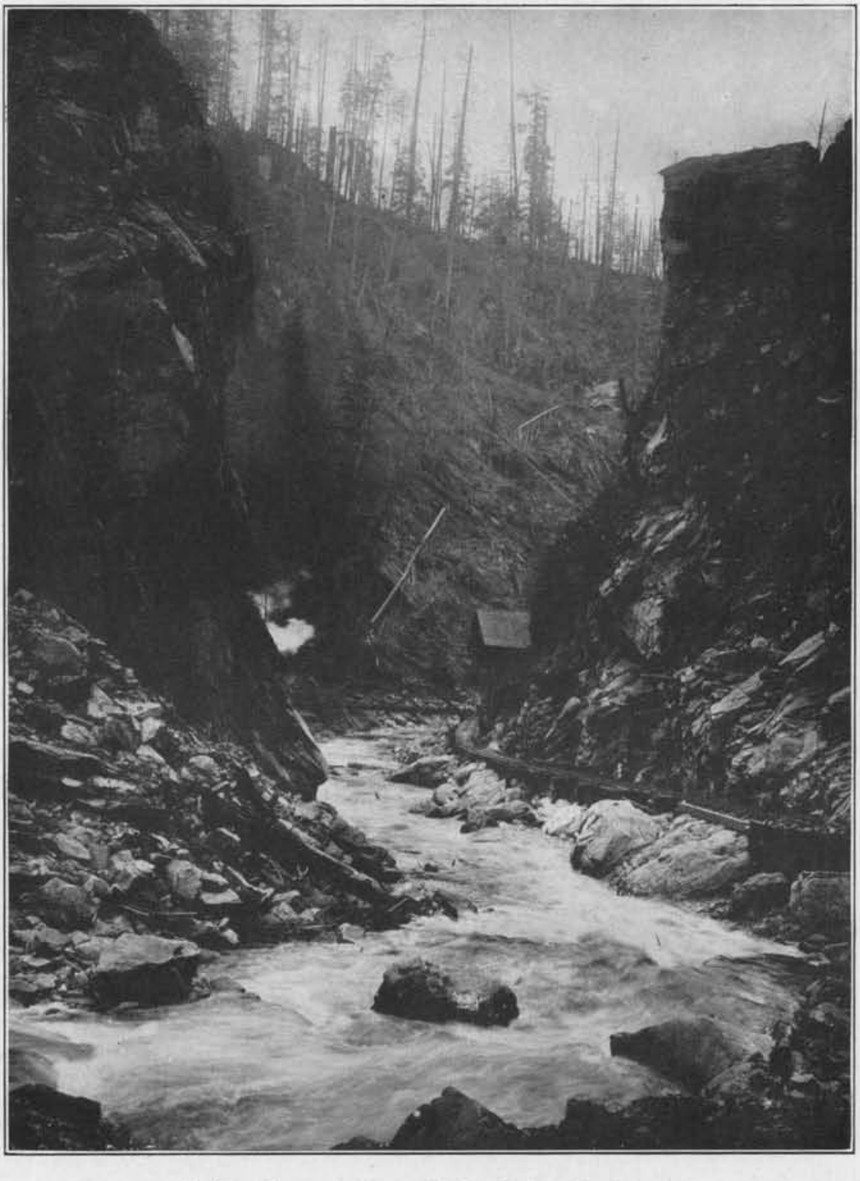
The Wilkeson-Carbonado field is drained by South Prairie Creek, Gale Creek, Evans Creek and the Carbon River. South Prairie Creek and Gale Creek rise on the north slope of Carbon Ridge and flow northwesterly, joining at South Prairie and then flowing southwesterly to the Carbon River at Crocker. Evans Creek rises in the lower hills of Mount Rainier not far from Spray Park and flows northerly, joining the Carbon River just above Fairfax. The Carbon River has its source in the Carbon Glacier on the north slope of Mount Rainier. [PLATE III.] It flows northerly and westerly and finally joins the Puyallup River as a tributary. Voigt's Creek, a tributary of the Carbon, flows over igneous outcrops west of the main part of this coal field.

The southern field lies between the Puyallup River near its headwaters and the Nisqually River. The principal tributary of the Puyallup is Neisson Creek. In the vicinity of Ashford, a few creeks flow south to the Nisqually, but the main drainage of these southern areas is the Mashell River and its numerous tributaries, all of which flow in a general westerly direction to join the main stream which finally flows into the Nisqually. Both the Puyallup and the Nisqually head in the similarly named glaciers on the west and south sides of the peak of Mount Rainier. [PLATE IV.]

All of these rivers exhibit similar phases of valley development. In their upper reaches they flow in wide valleys just below the glaciers from which they issue. From these wide valleys they plunge into narrow rock-walled canyons exposing deep sections of the sedimentaries and volcanics of the district [PLATE XII], and finally they come out on the lower plateau levels in very wide valleys between the hills of drift material. In the upper valleys the river filling is made up of large rock masses, more or less shingle-like in character; in the lower valleys the material is smaller, more rounded, and contains much silt. At Spiketon the depth of gravel over the rock bed is 200 feet.

The Carbon River canyon which extends from below Melmont to Wingate, a distance of three miles, typically shows the second phase of development. [PLATE V and PLATE VI.] The canyon at the points shown in the photographs is 400 feet deep and from 50 to 80 feet wide, cutting first a section through the gravel terraces, which here are at an elevation of 1,200 feet, and then through the sedimentaries, exposing many of the seams being worked by the Carbon Hill Coal Company.

These surface features, topography and drainage, have in a marked degree affected the development of the field. The thick cover of gravel, the heavy growth of timber and underbrush, and the scarcity of outcrops would have made prospecting practically impossible were it not for the channels cut by the streams. Long before any detailed technical studies had been made, prospect drifts were driven into the coal beds exposed along the creeks, and subsequent hillside tunnelling and



Carbon Canyon Above Rocky Point, Carbonado.

drifting exposed the outcrops along higher elevations. The continuity and correlation of isolated openings could not be made until columnar sections were made. Fortunately, South Prairie Creek gave a fairly continuous series of the upper beds; Gale Creek and its tributaries and Carbon River gave sections of the lower measures and it was possible to construct a geological column.

The railway to the Wilkeson mines followed the Puyallup River valley to South Prairie and thence up Gale Creek to Wilkeson. The Spiketon branch was built up South Prairie Creek from its junction with Gale Creek, and the South Willis branch was built from Wilkeson along an old creek bed. The problem of extending the Wilkeson branch to Carbonado was not so simple, as there is a steady climb from the level of Gale Creek to the level of the gravel terrace on which the town of Carbonado is built. The principal mines, however, are on the river, and to facilitate shipping a branch line was built from Crocker following the Carbon River to Wingate. [PLATE VII.] This line handles coal only. The extension of the railroad to Fairfax involved more climbing on the higher gravel terraces above the bed of the Carbon River. The road parallels the river, always above it at considerable elevation until Fairfax is reached, where the river is crossed just above high water mark. The mines on Evans Creek are about three-fourths of a mile from the Fairfax branch and 500 feet higher.

In the southern field the only transportation available is the Tacoma and Eastern branch from Tacoma to Ashford. Practically the whole of the Mashell district is without easy means of transportation, and this factor alone, were there no others, would tie up the development of these areas.

All of these facts have had a great share in the development of the present working field. With equal advantages as far as mine transportation and drainage and outside shipping facilities it can be seen that only those mines working on better grades of coal or more easily worked seams could secure the market and work at a profit. So it is that we find the most

Carbon Canyon. Rocky Point. Looking Downstream.

extensive development on the Burnett-Wilkeson-Carbonado series, and only in recent years have developments begun on the series below and above the one noted. The problem of sufficient water for coal washing has never been acute with the Pierce County operators, although in summer economy is necessary in its use. Two properties, Montezuma and Carbonado, have made use of available water power for running washing plants.

CHAPTER II.

STRATIGRAPHY.

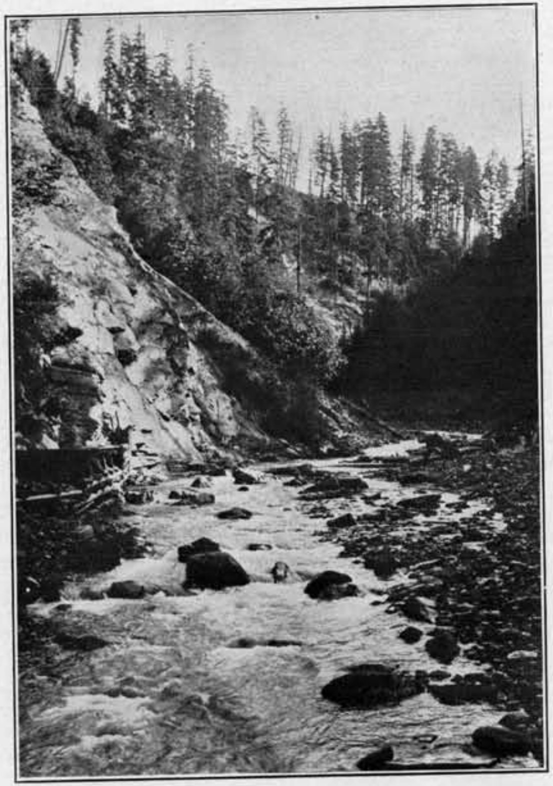
GENERAL STATEMENT.

The sedimentary rocks which make up the coal-bearing series of the Pierce County field are sandstones, shales, and the intermediate phases of transitional sandy shales or shaly sandstones of Eocene age. No conglomerates have been found within the areas under examination. The sandstones are of variable composition and texture, in some cases massive and coarse grained, in others banded or laminated and fine grained. In color they vary from white to buff and grey. With varying proportions of argillaceous matter they pass into the shaly sandstones or to the other extreme, sandy shales. Within any one bed all of these gradations may appear, but the common rule is to find the top or bottom of the bed slightly argillaceous, passing from this into the well-defined sandstone, either massive or laminated. Frequently micaceous and carbonaceous phases are found, and in many cases small stringers of bright clean coal can be found within sandstone walls. Sometimes these stringers become very large, large enough to be noted as seams, and very frequently the term "bogus seam" is applied to these, as they are usually not persistent or workable. [PLATE VIII A.] The sandstone beds are usually the best means of correlating the series from one part of a mine to another. Over larger distances there is no assurance that the bed will retain uniform characteristics. This is also true of the shales and the coals.

TERTIARY SYSTEM.

PUGET FORMATION.

The Wilkeson sandstone, noted by Bailey Willis, has been used to locally separate and define the upper and lower portions of the productive series. The Wilkeson sandstone is well exposed along South Prairie Creek near the railroad bridge east of Burnett; along Gale Creek and the railroad branch from



A. Carbon Canyon Showing Sandstone Outcrop.

B. Carbonado. Tipple and Shipping Yard on Carbon River.

Wilkeson to South Willis; and along the Carbon River below the bunkers at Carbonado. Although the Wilkeson sandstone forms an important key-rock, the divisions based upon its outcrops are more or less arbitrary and cannot be followed where there are no exposures on which to further extend the divisions. However, it is true that a wide belt, represented by these beds of sandstone, will not have any value as coal bearing land. Locally at Wilkeson the sandstone is quarried for building, foundation, and construction purposes. [PLATE IX.] The new schoolhouse at Wilkeson is built of this stone, and at Tacoma the stone has been employed in many of the newer buildings.

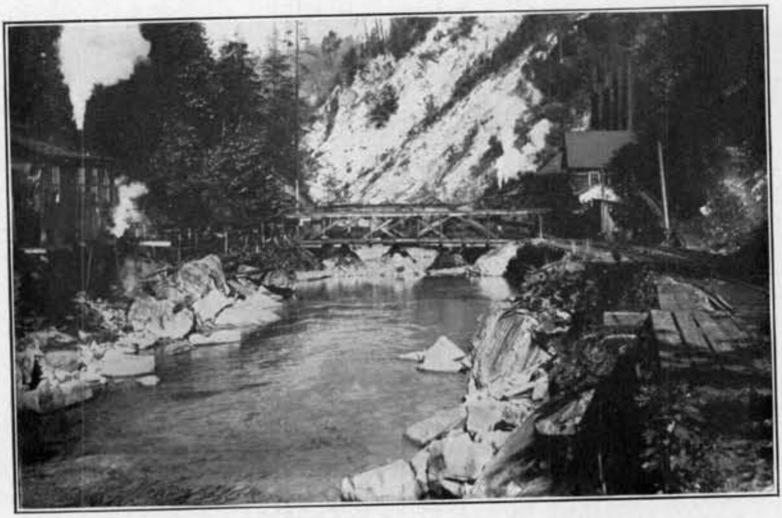
The shales of the Puget formation are usually grey to bluish grey, bedded and massive, having conchoidal fracture in some cases, and generally soft. Addition of sandy matter hardens the shale and makes it lighter in color. Near some of the dikes of igneous rocks the shales are baked to a hard slate. [PLATE X A.] Carbonaceous shales and bony shales are very common. The carbonaceous shales are black and soft, and are usually foliated. They are frequently associated with the seams of coal as distinct parts of the total bed. The bony shales are brown to black in color, sometimes hard, and are made up of grey shales carrying thin bands of coal or bony coal.

The intermediate or transitional rocks, the sandy shales and shaly sandstones represent phases of the sandstones and shales already described. They range in color, texture, and hardness between the two and the beds shade imperceptibly into each other. A sandstone bed or a shale bed at any point may be represented at any other point by a transitional bed.

Coal beds or seams vary in thickness, extent, and character throughout the entire field. In the "Report on the Coal Fields of Washington Territory,"* Willis reports "127 carbonaceous beds in the Wilkeson section, of which 17 are workable coal veins 3 to 15 feet thick." All of these coals are bituminous of different grades. The thickness and structure of the individual seams range from mine to mine. Typical sections of seams are

*Tenth Census of the United States, 1880, Volume XV.

A. Carbonado. Coal Seam and Sandstone Outcrop.



B. Carbon River. No. 1 South, Carbonado.

given in this report, and they will be further discussed in detail. Two forms of coal may be said to be present, viz.: pure coal and bony coal. The pure coal is usually bright and lustrous, soft and clean. The bony coal is dull and hard and contains a high percentage of ash. It is this bony coal in the beds which gives the relatively high ash percentage to all of the seams mined in the field.

The name Puget formation was early given to the coal-bearing measures of western Washington by C. A. White.* Its age is Eocene, as are the other coal-bearing strata of northwestern Washington. The thickness of strata measured along South Prairie Creek by Bailey Willis totaled over 8,271 feet. Further measurements made in rock tunnels at Burnett and on the eastern edge of the field indicate a total of 9,200 feet for the South Prairie section. The Carbon River section, likewise measured by Willis, has been increased from 4,953 to 5,600 feet by mine development. Although no section was measured along the South Willis branch evidence points to the fact that the total thickness of strata along this line and cutting across the east and south workings of the Wilkeson mines totals over 10,000 feet above the main anticlinal axis. The thickness of the Puget group represented in Pierce County is undoubtedly much greater than this amount. The main anticlinal fold, which characterizes the structure, plunges to the north, thus bringing up the lower members in the southern part of the field from Melmont to Evans Creek. No accurate measurements of this thickness have been made south of the Carbon River section, but it is reasonably safe to say that the total thickness will be found to be several thousand feet in excess of 10,000, possibly 15,000 feet as a total.†

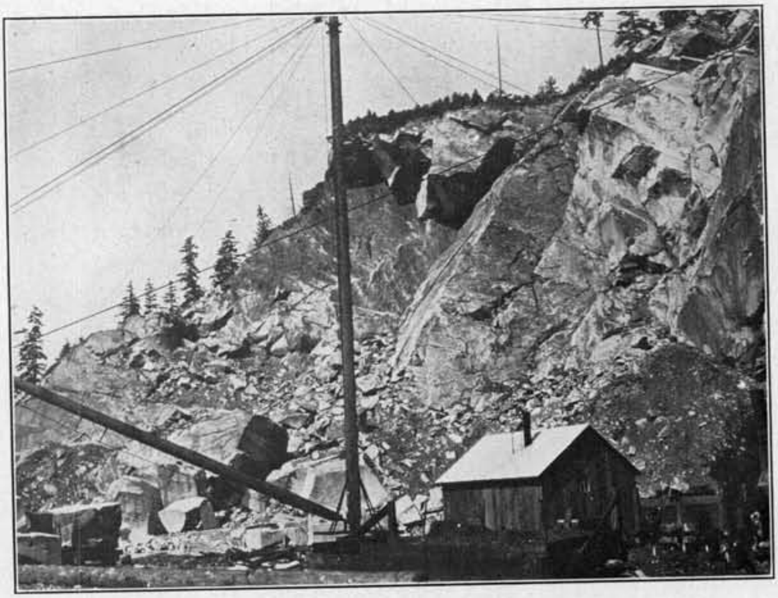
IGNEOUS ROCKS.

Associated with the members of the Puget group within the borders of the coal field are the Tertiary volcanic rocks which make up the foothills of the Cascades on the eastern boundary,

*Bull. U. S. Geol. Survey, No. 51, 1889, pp. 49-63.

† W. F. Jones, Bull. Geological Society of America, Vol. 25, No. 1, pp. 121-122.

A. Wilkeson Sandstone in Quarry Near South Willis.



B. Wilkeson Sandstone in Quarry Near Wilkeson.

and which also define the western limit of the field south of the Carbon River to the Nisqually, as shown in PLATE I. The coal field is seen to occupy a relatively narrow belt trending north and south between these larger bodies of eruptives. These lavas are andesites and in the area under discussion appear to be related to the pyroxene-andesites of Mount Rainier.* Within the narrow belt of sedimentaries, smaller igneous masses are encountered, as flows and dikes. These have been developed in the underground workings at South Willis, Wilkeson, Carbonado, Melmont, and Fairfax, with the greater preponderance of disturbance in the southern mines. The presence of these dikes and flows has had a marked effect in altering the character as well as the structure of the coal beds. All the evidence points to the conclusion that the greater masses of lava and the smaller intrusions are later than the deposition and folding of the Eocene sedimentaries.

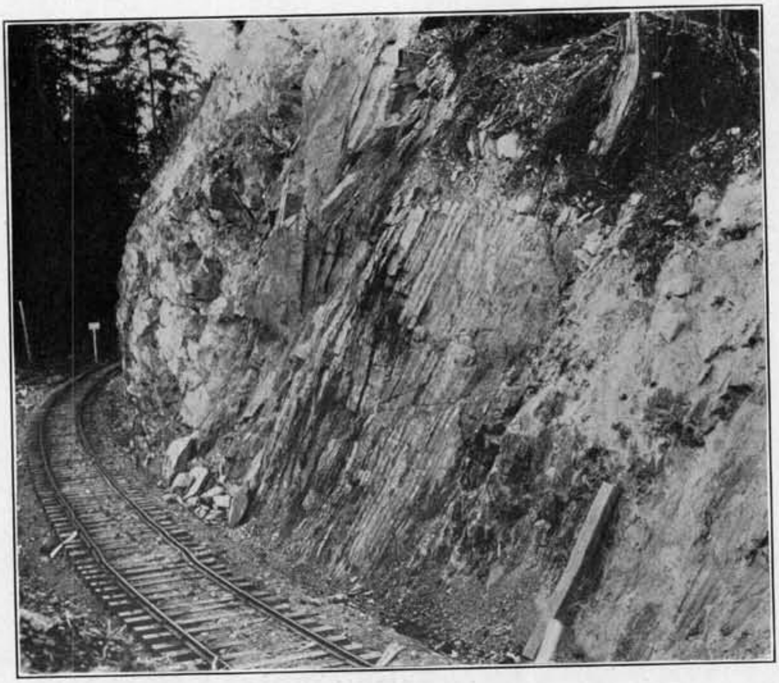
QUATERNARY SYSTEM.

PLEISTOCENE GRAVELS.

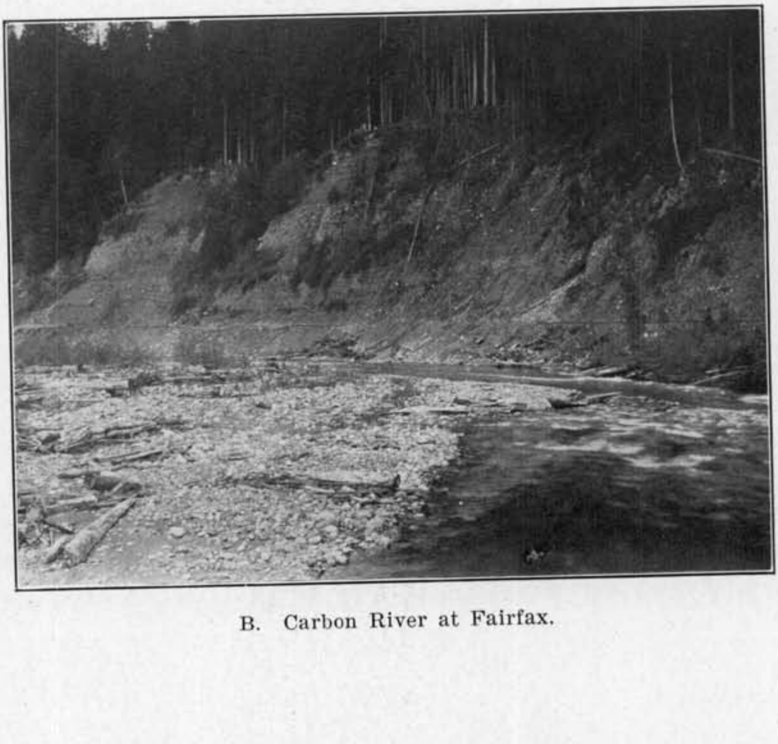
Covering both the sedimentaries and the igneous rocks are the glacial gravel deposits of Pleistocene age, which buried the earlier rock surfaces and formed the terraces which characterize the present lower topography.

Present day deposits are represented by gravel and silts from the glaciers of Mount Rainier [PLATES III B, X B] and by the material derived from the banks of older gravels which are being carried down the rivers and deposited wherever carrying capacity is checked or lowered. To this burden of natural material man is contributing the refuse of the coal washing plants.

*Rocks of Mount Rainier, 18th Annual Report, U. S. Geological Survey, Part II, 1897, pp. 416-423.



A. Contact of Andesite Dike and Shales Near Fairfax.



B. Carbon River at Fairfax.

CHAPTER III.

GEOLOGIC STRUCTURE.

GENERAL STATEMENT.

The structure of the Wilkeson-Carbonado field will be best understood by an examination of PLATE XI. In PLATE I is represented the workings at the different mines in the district. The course of the entries is indicated by the heavy black lines and the dips by arrows. The general course of the entries, except those of the mines on the east and north side of the Carbon River at Carbon, is west of north. At Spiketon and South Willis the dips are 60° to 65° to the east. At Burnett, east side, the dips are east, but in the western part of sections 16 and 21 they are to the west. The Gale Creek workings in section 28 are all on the west dip; the Wilkeson mines, sections 27, 34 and 3 are on both the east and west dips, the east dips varying from 50° to 60° and the west dips running up to 85°. In section 3, Township 18 North, the entries on the west dip swing around toward the west in a series of synclines and anticlines which represent the north side workings at Carbonado. The south side workings at Carbonado have a uniform dip to the west, averaging about 45°. At Melmont the course of the entries is slightly west of north, with dips both east and west. The Fairfax, Section 26 mine, shows similar conditions and so does the new mine in section 34. The Montezuma mine on Evans Creek, section 2, Township 17 North follows the same trend, but all the workings are on the west dip. PLATE XI, with a scale of 1,000 feet to one inch, shows the entries of the northern mines much more clearly.

From these isolated workings and from the sections obtainable along South Prairie Creek and Carbon River it is possible to correlate the coal beds and determine the general structure of the field from Burnett to Carbonado. South of Carbonado insufficient work has been done to correlate the beds with each other or with the series north of Carbonado, hence the discussion which follows will refer only to the field north of Carbonado.

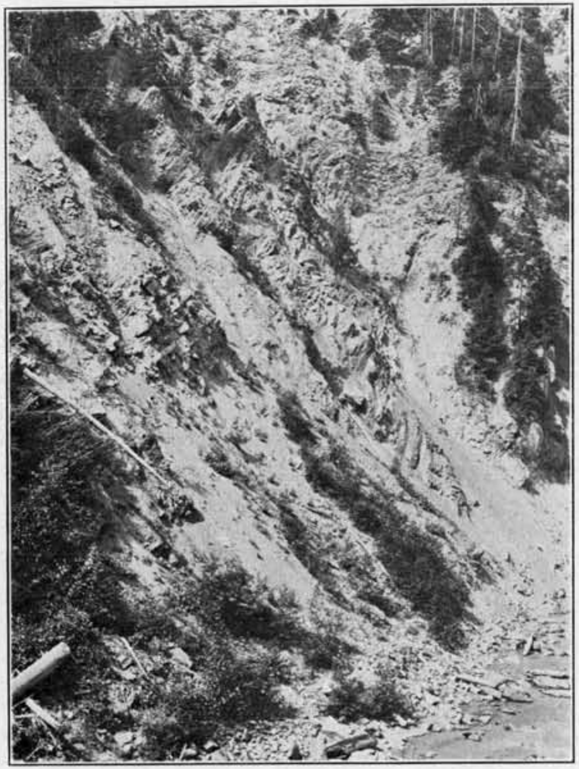
The general structure is a broad asymmetrical anticline having a dip of 60° on the east limb and a steeper dip on the west limb. This anticline has a plunge to the north of about 10°, causing the mine entries on the east and west dips to swing toward each other on the north and to separate toward the south. The east limb of the anticline appears to be quite regular in structure, but the west limb is folded into a series of minor anticlines and synclines which reach their maximum development in the Carbonado mines. At Burnett the structure is a simple anticlinal fold; at Wilkeson along an east-west line through the center of sections 28 and 27 the west limb shows a small synclinal and an anticlinal fold with two distinct axes west of the main axis; at Carbonado along the north lines of sections 5, 4, 3 and 2, four anticlinal and three synclinal axes are recognized on the main west dip of the major fold. The transition from the main fold at Burnett to the sharper folds at Carbonado is made through the long gentle fold in section 28. The east limb of the major anticline shows evidence of secondary folding in the east part of section 3 and in section 2. A synclinal axis and an anticlinal axis having a northeasterly strike are recognized in section 2 with steeper dips than in the north. This eastern limb has not been explored as thoroughly as the western, but it appears to be far more regular and less folded than the western. All of these folds exhibit the characteristic north pitch.

The axis of the main anticline extends from the west portion of section 16 at Burnett southeasterly across section 21, over the northeast portion of section 28 and the southwest corner of section 27, through 34 and 3 with a general trend of South 20° to 30° East, and apparently continues across the field for many miles. The minor axes on the west side show the same general trend, but on the east limb the axes so far exposed show a northeasterly strike.

SUBDIVISIONS OF THE PUGET FORMATION.

Within the Puget group, Willis made three local subdivisions, viz.: the Burnett, the Wilkeson, and the Carbonado formations. The Burnett formation is represented by the upper beds exposed along South Prairie Creek, which include the seams now worked at Spiketon and South Willis and the abandoned mines known as the Acme and the Black Carbon in sections 15 and 22. The Wilkeson formation consisted mainly of the Wilkeson sandstones lying above the Burnett No. 1 seam and below the upper series just referred to. The division was an arbitrary one based on the easy recognition of the Wilkeson sandstone as a key-rock rather than on difference in characteristics. The Burnett No. 1 seam was made the bottom of this formation, and below this the productive series represented by the Burnett-Wilkeson-Carbonado mines was termed the Carbonado formation. The thickness of the Carbonado formation at Carbonado where it reaches its maximum is about 2,200 feet. At Burnett it is only 900 feet. The thickness of the Wilkeson formation at Burnett, as given by Willis, is 1,000 feet. This thickness, because of its arbitrary determination, is not important except for the fact that it would tend to increase or decrease the thickness of the Burnett formation according to the point of division. Assuming a thickness of 1,000 feet for the Wilkeson on South Prairie Creek, the Burnett formation is about 7,500 feet thick. Within this thickness, at a point about 4,650 feet above the Burnett No. 1 seam, occur several workable seams which are of commercial importance. We may thus summarize this division according to the order of its economic importance into (1) the Carbonado formation which consists of the lower and most important seams; (2) the Wilkeson formation which is practically barren; and (3) the Burnett formation made up of the uppermost beds exposed in the Pierce County area and having within it commercial beds of coal of a quality not so high as those of the lower productive formation.

The Wilkeson formation consists of a well defined structural unit which can be best recognized on each flank of the main



A. Carbon Canyon Looking Upstream From South IX Tunnel.

B. Carbon Canyon Looking Downstream From South IX Tunnel.

anticlinal axis of the field in sections 28, 27 and 22, particularly in the quarries along the South Willis branch of the railroad where the dips are all to the east. Although not so prominent on the west dip, the formation is exposed in section 28 and in the Carbon River section below the mines.

The Burnett formation forms the greater part of the east limb of the major anticlinal fold with a uniform strike and dip in those northern sections of the field in which it is exposed by outcrops or mine workings. On the east, the Burnett formation makes a sharp contact with the volcanics which overlie it. The extreme upper portion of the Burnett, east of the mines at Spiketon and South Willis, shows evidence of metamorphism due to the igneous material, but no evidence of economically important seams. Little is known about the extension of the Burnett formation on the east dip southward beyond section 26. On the west dip the only recognizable portion of the Burnett formation is on Carbon River above the Wilkeson formation. The entire thickness is not exposed, and it is probable that the seams equivalent to those worked at Spiketon are concealed under the drift deposits west of the exposed section.

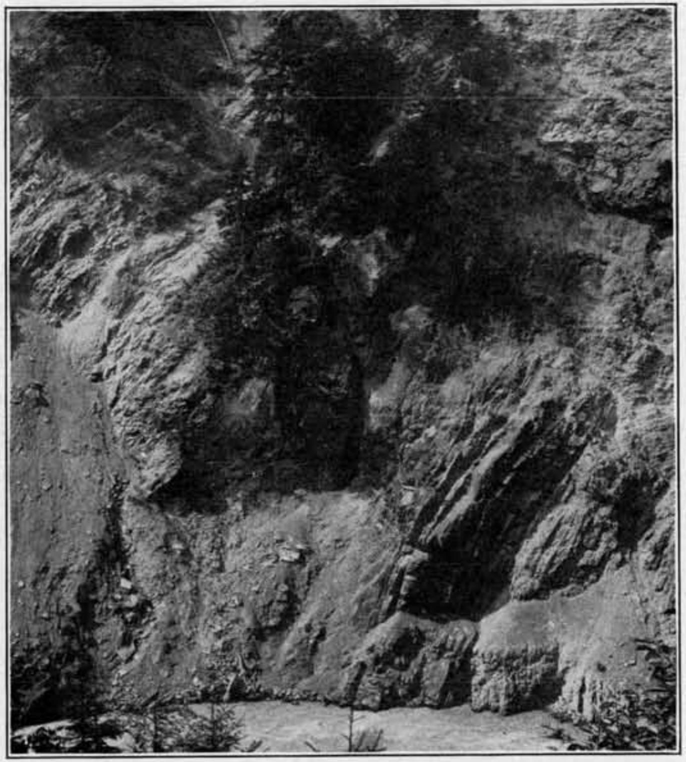
The Carbonado formation, which contains the principal producing mines, is the most interesting and complicated from a structural standpoint. Practically the entire tonnage of Pierce County comes from the seams in this formation, and this means that the greatest mine development is to be found here. Omitting, for the present, any consideration of the beds south of Wilkeson and Carbonado and devoting the study to the northern mines, a more detailed analysis will be made of the structure of the field.

DETAILED STRUCTURE OF FOLDS.

THE BURNETT-WILKESON ANTICLINE.

The main Burnett-Wilkeson anticline dominates the field as the most pronounced structural axis. [Plate XI.] East of this a small basin called the eastern Wilkeson coal basin is developed in section 2, Township 18 North. West of the main anticline, the complex structure at Carbonado is developed. The

A. Carbon Canyon. Anticlinal Fold.



B. Carbon Canyon. Anticlinal Fold at Axis of Central Carbonado Basin.

basins are successively designated the western Wilkeson, the eastern Carbonado, the central Carbonado, and the western Carbonado, following the lines suggested in Bailey Willis' structure map of the coal beds given in the Tacoma folio. Since that map and report were made, extensive mine development has thrown much light on the structure of the field and this new material has been used in constructing the structure map.

In constructing this plate all the available data on strikes and dips of the coal and associated beds obtainable from surveys, mine maps, and rock tunnel sections was compiled and first used in making the mine map [PLATE XI], and the cross-sections [PLATES XVI to XXI]. From such data the anticlines and synclines and important faults were platted at the elevation of the mine workings. On the assumption that the seams were regularly continuous in strike and dip, the intersections of the anticlinal and synclinal axes, the more important faults, and the coal seams on a plane at sea level were drawn. Thus, the map represents the structure of the field as it would be traced out on a surface several hundred feet below the present workings. In only one or two instances are the present mine workings near sea level. In the interpretation of this structure, minor foldings and faults, which are usually present but which cannot be foretold in advance, are not considered. Only the broad general structure has been attempted.

THE EASTERN WILKESON BASIN.

The eastern Wilkeson basin has been traced out by recent prospecting work in section 2. This work indicates a synclinal axis on the east side of the main Burnett-Wilkeson anticline with the characteristic north pitch but having a northeast trend. The east dipping Wilkeson seams appear to swing around this syncline and reappear on the east dip after passing around an anticlinal axis which also has a northeast trend. Southward the seams resume their regular northwest-southeast strike with slightly steeper dips to the east. This basin, when opened up by mine development, will throw much light on the relationship between the Wilkeson-Carbonado and the underlying series of seams.

THE WESTERN WILKESON BASIN.

The western Wilkeson coal basin is well defined in section 28. The Gale Creek workings are on a west dip; the Hi Davis mine is on an east dip, and the workings at Brier Hill are on the nose of an anticline which pitches to the north. These facts, together with earlier data, indicate that the basin has a southeasterly trend across section 28 and is cut off by the overthrust fault which intersects the Wilkeson seams on the west dip. The extension of this basin beyond the fault is found in section 3 in the southeast workings of the Wilkeson mines. A well defined anticlinal axis separates the southeast from the southwest workings which extend into section 4, and the general trend of the southeast workings indicates a synclinal axis east of the present levels. Undoubtedly this synclinal axis and the shallow basin which accompanies it represent the overthrust portion of the western Wilkeson basin of section 28. The anticline in section 28, already referred to, according to this interpretation, is the same as that in the western half of section 3. Thus it will be seen that the three southwest Wilkeson seams mined south of the great overthrust fault correspond to the west dip of the western Wilkeson basin and not to the west dip of the main anticline as has been heretofore supposed. The swing in the course of South 7 seam at Wilkeson and the changes in the direction of the levels of the south seams is explained by the fact that there is a slight arching or doming in the anticline, causing a south pitch for a short distance south of the rock tunnels, but which swings back to the north pitch toward the center of section 3. The southeast workings will intersect the synclinal axis and the gangways will then turn to the north and intersect the fault. The basin thus opened will probably be very shallow.

THE EASTERN CARBONADO BASIN.

If we now examine the Carbonado workings in detail we shall find that three distinct basins are present north of the river. In the rock tunnel from North I east to the Wilkeson seams in section 4 a synclinal axis is found at a point about 500 feet west of the line between sections 3 and 4 and an anticlinal axis is present about 300 feet west of the North I gangway. The syncline determines the axis of the eastern Carbonado basin, and the swinging of the Wilkeson gangways to the southwest indicates the approach to the axis of the basin. The anticline is marked by broken ground which indicates the position of an overthrust fault.

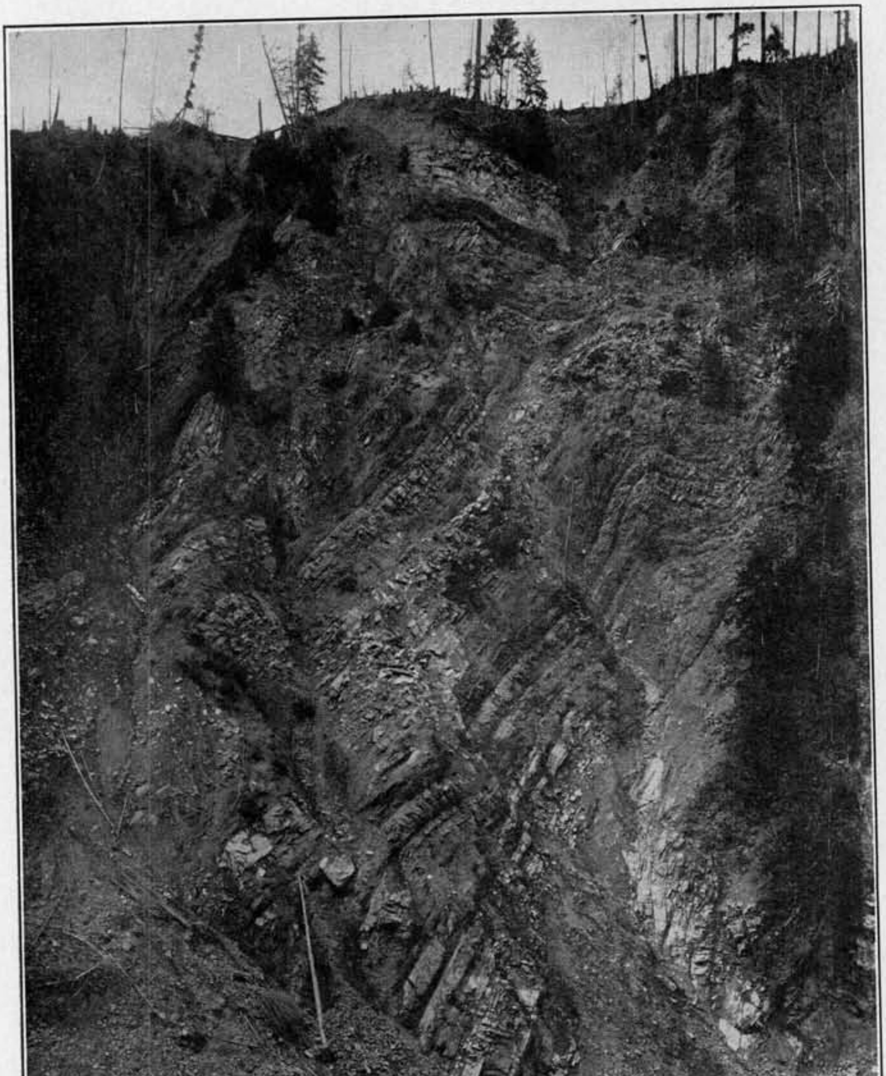
THE CENTRAL CARBONADO BASIN.

The central Carbonado basin is clearly shown by the workings on the Gem, North I and North IV seams in the central part of section 4. There is no question about this basin nor of the anticline which separates it from the west Carbonado basin. This anticline is shown in the mine workings and it is well exposed in the canyon of Carbon River above the upper bridge. [Plates XIII and XIV.] Local faulting at the "nose" of this anticline on No. 1 North disturbs the continuity of the workings at this point but does not affect the major structure.

THE WESTERN CARBONADO BASIN.

The North I rock tunnel, beginning at the river just north of the foot of the incline, shows an anticline and a faulted syncline in its course toward the northeast. The north workings in section 5 and in section 32, Township 19 North, indicate the position of the anticline, and the syncline is shown on the No. VI North water level and on the water level of No. VII North in section 4 north of the river. The syncline can be observed in the river canyon. Throughout most of its length, however, the synclinal axis is in an overthrust fault. This marks the western Carbonado basin.

The transition from the main fold of the Burnett-Wilkeson anticline to the Carbonado basins is made through the long fold, indicated in sections 28 and 33 [Plate XI], on the Win-



Carbon Canyon. North Bank Above Rocky Point.

gate and Miller seams. The exact courses of the axes of the Carbonado basins and the courses of the gangways of the seams at sea level should be interpreted only in a general way for the central and the eastern Carbonado basins as these were constructed from the most meagre data on the assumption that the structure of these upper seams would correspond to that shown in the lower seam workings. Careful study of mine developments as these sections are more thoroughly explored will lead to the exact determination of structure.

MELMONT-FAIRFAX-MONTEZUMA AREA.

The structure of the field south of Carbonado and Wilkeson has not been accurately determined and until further field work is done no exact statement of structure and correlation can be made.

Below the lowest exposed seam in the Carbon River section, South VIII, the andesite dike, through which the Carbon has cut its channel, is the only rock exposed until Melmont is reached. The Melmont rock tunnels show a series of sediments older than those of the Carbonado formation because they underlie these on a north pitching or plunging series of anticlines and synclines. These basins conform in a general way with the Carbonado basins north of the normal fault.

South of the Melmont series, a few outcrops are present along the railroad branch to Fairfax. In section 26 the old Fairfax mine, now abandoned, gives an additional series which also shows the characteristic north plunging anticline. Two large normal faults cut these workings. Still further south the present Fairfax mine in section 24 and the Montezuma mine in section 2 develop a number of workable seams and throw some light on general structure. The Fairfax area is one of much disturbance and faulting.

Cross-sections of the Melmont rock tunnel and of the Fairfax Section 34 tunnel, together with other field data, make it appear that this series represents an additional thickness of several thousand feet which may be added to the Carbonado, or still better, may be called a new formation. The structure so far revealed indicates that the Melmont-Fairfax section occurs in a series of folds or basins on the west side of the main axis of the major anticline which has continued its general southeasterly trend but which may be faulted and displaced in this area of greater disturbance.

THE PUYALLUP-ASHFORD AREA.

The areas around the Mashell river and Ashford are highly broken by faults and intrusions of igneous rock. While they contain coal, they are not commercially minable, because of the structural difficulties involved. In addition to this, the coal shows high ash.

Development in these areas has taken the form of prospect openings. At Ashford a long rock tunnel was driven to intercept a seam which outcropped on the ridge north of the town. The mine thus developed shipped nearly a thousand tons of coal but it has been closed for several years.

The seam opened at Ashford consists of two benches, figure 15, analyses of which are given in the appendix. The coal is reported to be of coking quality, but has excessive ash unless carefully washed and prepared. The seam has a variable northwest strike, dips 38° east, and is very much disturbed by a fault. Under these conditions the coal can hardly be considered as of present economic importance, consequently the structure will not be considered in this report. In passing, it might be said that in a general way the main structure corresponds to that of the areas just to the north.

SYSTEM OF FAULTS.

OVERTHRUST FAULTS.

Intimately connected with the folding of this area is the series of overthrust faults which traverse the field. These faults in order from the east to the west are (a) the fault extending from the South Willis branch in section 27 northwestward through the Burnett workings on the east dip; (b) the fault extending from the Gale Creek mines southeastward through the Wilkeson workings on the west dip; (c) the fault crossing the eastern half of section 33 and section 4 near the axis of the central Carbonado basin; (d) the fault along the synclinal axis of the western Carbonado basin in the western part of section 32 and the eastern part of section 4. Overthrusts of lesser extent are found in the Burnett mines in the southwestern portion of section 16 and in the southeastern quarter of section 21. In the Wilkeson mines the north end of the south workings on seams 1, 2 and 3 are in a fault, which is reported to be an overthrust, but these workings were inaccessible and the data could not be verified.

NORMAL FAULTS.

The normal faulting in the field followed the overthrust faulting and, in general, crosses the dips of the seams. The great normal fault at Carbonado, which crosses the river, has thrown the measures to the east, and a second normal fault, paralleling the first and south of it has faulted this displaced portion, also to the east. Some normal faulting in the southern Burnett workings on both the east and west dips of the seams has been found, but these workings are now inaccessible and the exact structure could not be determined.

In addition to the faulting already described, small local faults are frequently encountered in the workings. Generally they are normal faults of very small displacement and the seam can be readily followed by the traces of coal left as thin leaders or stringers in the fault plane. This faulting is well shown in the windings and turnings of the main entries and this feature is characteristic of the entire field.

DESCRIPTION OF FAULTS.

The Burnett fault is a hinge-fault or a pivot fault, that is to say, it has a point of zero displacement, north of which the measures have been overthrust with a displacement at the north end of Burnett of 1,000 feet and south of which the fault is normal in character. The pitch or hade is nearly vertical to the east. This zero point is near the railroad branch to South Willis, just south of the Burnett gangways on the east dip of No. 1 and No. 2 seams. The normal fault has not been traced south of this point, but it will limit the extent of the workings on the lower levels of the No. 5 Wilkeson seam if it extends any distance. The overthrust fault causes the No. 1 and No. 2 Burnett seams to repeat themselves on the east dip and it is also responsible for bringing No. 3 seam up to the level of the workings on the second level rock tunnel. The north end of this fault cuts both the east and west dips of No. 3 seam. A minor overthrust has caused part of the faulted section of No. 1 seam on the east dip west of the fault to be repeated so that three east dips of No. 1 seam are actually present at this point. No. 1 and No. 2 Burnett on the west dip at the north end of the property are similarly caused to reappear by another overthrust of 800 or 900 feet displacement.

The Wilkeson overthrust fault begins at the Gale Creek mines with a very small displacement which increases in magnitude going south until No. 7 Wilkeson, one of the underlying seams, is brought up to the level of the workings on the No. 1, 2 and 3 west gangways. At this point the displacement is from 1,500 to 2,000 feet. The hade is slightly to the west. It will be noted that this fault has cut the axis of the western Wilkeson syncline and anticline and caused them to reappear in the southeast and southwest workings. The workings on Wilkeson Northwest 1, 2 and 3 seams are on the west dip of this basin and not on the faulted portions of the west dip of the main fold as has heretofore been believed. This fault has not been traced north of the Gale Creek mines, but if it extends to the north, which is problematical, it will probably be found to be of the hinge-type. The gangway on South 7 apexes south of the fault. This indicates a south pitch of the anticlinal axis and a consequent dome between this point and the north pitch. Such minor dome was present but the fault has passed through it and traces of it are lost except at this point. The anticlinal fold of the western Wilkeson basin south of the fault shows a narrowing and a widening indicating the basin between the south pitch just described and the regular north pitch which is reappearing in section 3.

The central Carbonado fault was encountered in the water level of North I seam and in the rock tunnel west from this seam to the Wilkeson workings and cuts the axis of the anticline between the eastern and central basins. The hade is to the west and the displacement along section GG′ [Plate XI] is estimated to be 1,000 feet. The displacement is probably less at the northern end of the fault.

The western Carbonado fault is encountered in practically all of the workings of the western basin and follows closely the line of the synclinal axis of this basin. Its hade, as in all of these faults, is west. It would appear that the displacement is least at the south end of the fault as the syncline appears to be quite regular here, and the maximum at the north end is about 400 to 500 feet.

The great normal fault at Carbonado shows a maximum horizontal displacement of 1,200 to 1,300 feet; the fault paralleling this has a maximum horizontal displacement of 300 feet. The displacements are least at the east end of these faults, indicating their hinge or pivot character. The normal fault separating the Burnett from the Gale Creek workings has a displacement of only 250 feet. The other normal faults are of relatively small displacement.

CORRELATION OF SEAMS.

CARBONADO FORMATION.

The complex folding and faulting, the marked variation in rock interval between seams, the differences in the character of the strata and the seams themselves, as well as the fact that the mine workings are largely isolated from each other have made difficult the exact correlation of the seams in the Carbonado formation. Some identifications are readily made; others are more difficult, and not until more data is obtained can the entire correlation said to be final and exact.

The following correlation is given for the seams opened in the different mines:

CORRELATION OF SEAMS—BURNETT TO CARBONADO.

BURNETT	GALE CREEK	WILKESON	CARBONADO	
			North of normal fault	South of normal fault
Burnett No. 1	Peanut No. 2	Wilkeson No. 5	North III (Miller)	South II (Miller)
Burnett No. 2	Peanut Queen	Wilkeson No. 4	North VI (Wingate)	South I (Wingate)
		Unnamed	North V	South V
Burnett No. 3		Wilkeson No. 3	North IV	South IV
		Wilkeson No. 2	{ North II North I	Burnt
		Wilkeson No. 1	Gem	South III
		Unnamed (Denton)	Morgan (North VII)	South IX
		Unnamed (9-Foot)	Bruiser	South VII
			Unnamed	
			Unnamed	
		Wilkeson No. 7	North IX	Seam opened in tunnel
			South X	South VIII

PLATE XV is a graphical table showing the rock intervals between these seams and contains an average of all the measurements thus made. A study of these tables and the sections given in PLATES XVII to XXI indicates that the correlation of the upper seams of the series is exact. Below this, there is some uncertainty in regard to the correlation of the Carbonado workings on the north and south sides of the normal fault. Some of the older workings are inaccessible and until the seams can be studied and measurements made of the interlying sediments this correlation will always be indeterminate and problematical.

Burnett No. 1 on the east dip is the same as Wilkeson No. 5. The same seam on the west limb of the anticline is represented by the Peanut No. 2 in the Gale Creek mines but has not been opened in the Wilkeson mines. At Carbonado, the Miller, opened in North III and South II, is the equivalent.

Burnett No. 2 on the east dip is equivalent to Wilkeson No. 4, and on the west dip is the same as the Queen at Gale Creek. It is not represented on the west side at Wilkeson. The Wingate at Carbonado is the same seam under the numbers North VI and South I.

Burnett No. 3 and Wilkeson No. 3 on both dips are the same. A rock tunnel driven east from the Queen at Gale Creek just failed to strike this seam, probably because at this level, the seam is flattening and swinging toward the axis of the anticline. The folding and faulting in the west Wilkeson basin and in the Carbonado basin causes this seam to reappear in all the sections. At Carbonado the local names are North IV and South IV.

The Wilkeson No. 2 is mined on both dips at Wilkeson and in the various basins at Carbonado. North II and North I at Carbonado are the same and equivalent to Wilkeson No. 2. On the south side at Carbonado, the equivalent seam is found in the rock tunnel from South IV to South III, but it is badly burned and has never been opened. The name Burnt seam has been locally given to it.

Wilkeson No. 1 follows the general development of its associated seams. At Carbonado it is known as the Gem on the north side and as South III in the south side operations.

Lying above Wilkeson No. 3 is a seam which at Carbonado is known as North V and South V. This seam shows up in the surface sections at Wilkeson and in one of the rock tunnels at Burnett, but it has not been opened at these places. It is therefore indicated in the Wilkeson column as unnamed.

The correlation up to this point is correct. In the Wilkeson section two small unnamed seams are present between No. 1 and No. 7 but they are only of passing interest. In the Carbonado sections, on the north side below the Gem, the following seams have been opened: The Morgan, known as North VII and North XI; the Bruiser; two unnamed seams; North IX; and South X. These seams are seen south of the North I rock tunnel. On the south side, below South III, which is the equivalent of the Gem, are South IX, South VII, an unnamed seam opened from the rock tunnel to South VIII, and South VIII. This latter rock tunnel undoubtedly holds the key to the correlation as there is a vertical interval of nearly 600 feet here which has not been measured. On the evidence of the other available data the correlation already given has been made. This makes the Morgan equivalent to the South IX, the Bruiser equivalent to South VII, and North IX equivalent to the seam opened from the tunnel to South VIII. South X and South VIII are the same without question. Wilkeson 7 has been tentatively correlated with North IX, simply on the basis of rock intervals.

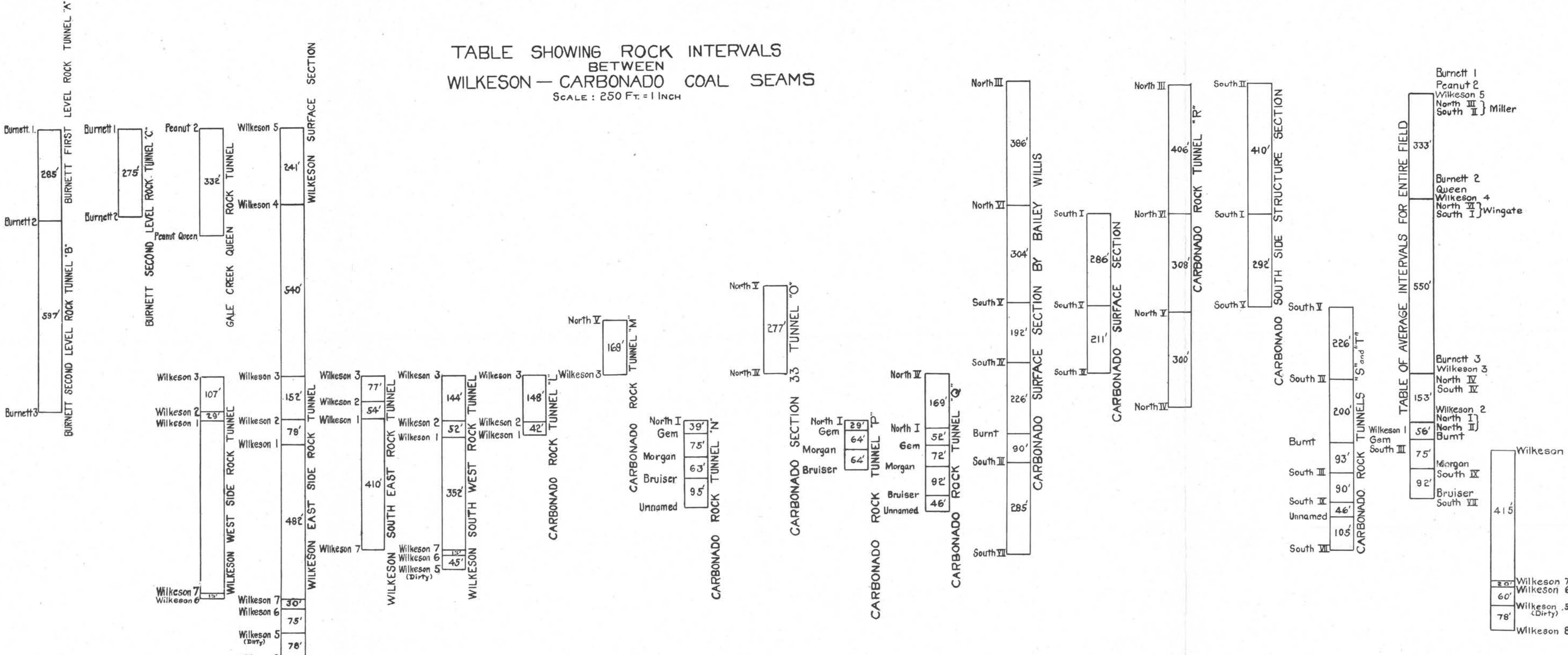
There are many objections to the correlation just given. The exact identity of the Morgan or North VII is in doubt. Among the men operating the mine South VII is believed to be the same seam and there is sufficient similarity in some of the coal sections to warrant this belief, but a correlation based on rock intervals and the presence of interlying seams makes this untenable, unless it can be shown that there has been some confusion in regard to the name Morgan on the north side. The section of the Bruiser seam on the north side does not correspond well with South VII section, with which it is correlated, but on the basis of correlation already indicated, these must be so placed in the scale. Until further data can be obtained from measurement of the tunnel to South VIII no light can be thrown on this problem.

BURNETT FORMATION.

Correlation of the uppermost seams exposed in the Pierce County field is not entirely possible because they have not been developed as extensively as the seams in the Carbonado formation. The mine workings at Spiketon and at South Willis reveal certain important facts [Plate XVI] and on this basis the following correlation has been made of the more important seams of the Burnett formation:

TABLE SHOWING ROCK INTERVALS BETWEEN WILKESON — CARBONADO COAL SEAMS

SCALE: 250 FT. = 1 INCH



CORRELATION OF SEAMS—SPIKETON AND SOUTH WILLIS.

SPIKETON		SOUTH WILLIS
North Side of South Prairie Creek	South Side of South Prairie Creek	
		CROCKER SEAM *Interval* 112′
		BIG SEAM *Interval* 153′
NO. 12 SEAM *Interval* 36′		SHALE and COAL SEAM *Interval* 37′
NO. 11 SEAM *Interval* 48′		JONES SEAM *Interval* 35′
NO. 10 SEAM (Lady Wellington) *Interval* 313′	WINSOR SEAM	WINSOR SEAM *Interval* 486′ (*In which three seams are said to be present.*)
NO. 9 SEAM (Boiler) *Interval* 155′		
NO. 8 SEAM (Pittsburg) (*Interval* 182′ seam)		6 FEET SEAM (Prospect) (*Interval* 190′ SNELL)
Interval 339′	*Interval* 870′	*Interval* 486′
NO. 7 SEAM	PROSPECT OPENING (*Interval* 113′ Acme) (*Interval* 173′ Acme entrance	CHAMPION SEAM (*Interval* 170′ BURNT SEAM)
Interval 261′	*Interval* 252′	*Interval* 237′
NO. 6 SEAM	PEACOCK SEAM *Interval* 1300′	PEACOCK SEAM
	PROSPECT OPENING *Interval* 189′	
	DRIFT OPENING *Interval* 172′	
	DRIVER OR BLACK CARBON SEAM	

All of these seams have an average dip of 60° to the west and a strike generally averaging North 15° West to North 20° West on the east limb of the main Burnett-Wilkeson anticline. The No. 12 bed at Spiketon is identified with a small shale and coal seam in the South Willis rock tunnel. The No. 11 and the Jones are the same. These are small seams of no present importance. No. 10, the Lady Wellington, and the Winsor are the same and their workings will connect across South Prairie Creek. Below the Lady Wellington, No. 9, or the Boiler seam, has been opened at Spiketon, but its equivalent has not been seen at South Willis. Three seams, however, are said to be present in an interval of 486 feet below the Winsor and the

Boiler seam must be one of them. No. 8, the Pittsburg, is one of the important seams at Spiketon, but it has not been traced south of the railroad. At a point 486 feet below the Winsor at South Willis in a little draw a prospect was opened on a seam reported to be 6 feet thick. This is probably the equivalent of the Pittsburg. The Snell at South Willis is 190 feet below this prospect. This may be the same seam as that worked in the Snell mine in section 26, and its equivalent is to be found in a coal and bone seam in the Pittsburg rock tunnel 182 feet below the Pittsburg. No. 7 seam and No. 6, opened in the rock tunnel, are correlated with the Champion and Peacock, respectively, at South Willis. The rock interval between the 6-foot seam and the Champion at South Willis is considerably greater than at Spiketon, but the two seams are similar in character. No. 7 is represented on the south side of South Prairie Creek somewhere near a prospect opening, now caved in. West of this opening is a series of openings which represent the old Acme mine. At the present time the Acme seam is burning. One of these seams was opened as a drift and then cross-cutted to the Acme. The interval below the prospect opening corresponding to No. 7 is 173 feet and this agrees with the interval between the Champion and the Burnt seam, 170 feet, at South Willis, making it appear that these seams, the drift underlying the Acme and the Burnt, are the same. The so-called Peacock opening at this point agrees well in interval and character with the No. 6 and the Peacock at South Willis.

Below these seams in the South Willis and the Spiketon north side sections no more openings are known. On the south side of South Prairie Creek three openings are present, one 1,300 feet below the Peacock, then an interval of 189 feet, and underlying this at a depth of 172 feet is the water level to the Driver or Black Carbon seam.

WILKESON FORMATION.

Just east of the Burnett openings on the line of the branch to Spiketon a small seam is exposed near the track and is locally known as the Peacock, but it is not the same seam as the Peacock of South Willis and Spiketon. A number of other small seams appear within the belt of the Wilkeson formation along South Prairie Creek.

On the west side of the syncline of the Western Wilkeson basin, the Hi Davis and the Brier Hill mines have been opened in the west half of section 28. Both these seams are in the Wilkeson formation overlying the Peanut or Burnett No. 1 seam but they are of no economic importance and cannot be definitely correlated.

SUMMARY OF DEVELOPMENT OF STRUCTURE.

In the period of deposition of the Puget formation with its associated beds of coal, the sediments were deposited in estuaries of fresh or brackish water. Swamp conditions prevailed at various times during this period, and to the accumulation of vegetal matter which was buried under the sediments we owe the coal beds. No typical marine fossils have been discovered in the area of the Pierce County field, but many plant remains and brackish water molluscs have been found and described.

The accumulation of deposits, now represented by a thickness of over 10,000 feet of sandstones and shales, under the influence of subsidence and accompanying compression was flexed and folded into the broad anticlinal arch and minor basins already described. Completing and accompanying the flexing into the broad major fold and the sharper minor folds having general dips of 50° to 60° on the east and dips up to 85° on the west limbs of the folds, a series of overthrust faults was developed along lines also trending northwest and southeast. These faults have had an important influence in the mining development of the field. As already noted, they are, in order from east to west, (a) the Burnett, on the east dip from Wilkeson north to Burnett; (b) the Wilkeson, on the west dip from Gale Creek south; (c) the central Carbonado; and (d) the western Carbonado. In addition to these, there are two overthrust faults of minor importance in the Burnett mines, one on the east dip in the southeast quarter of section 21 and one on the west dip in the southwest quarter of section 16.

After the structure had thus been determined, further faulting took place, mainly normal in character, the planes of the faults cutting across the measures in a more general east-west direction. The best example of this is in the great normal fault separating the north from the south side workings at Carbonado and the fault paralleling this in the south side workings, both of which trend about North 45° West. A normal fault of irregular extent cuts the south workings at Burnett. In addition to these faults of major importance in the general structure, local faults cut the seams throughout the entire field, presenting constant problems in mine operation. These have not been studied in detail as they represent purely local problems which must be accepted as part of the difficulty of mining steeply dipping seams.

The exact history of the development of the structure described cannot be accurately determined. Certain facts, however, can be noted, but the rest is hidden in lack of accompanying structural data. The direction of pressure was from the northeast acting toward the southwest, or from the southwest acting toward the northeast, the main axes of the folds trending North 15° to 20° West. It is probable that the direction of major pressure was first from the northeast as we find the greater fold on this side and the minor folds on the southwest. The dips of the folds to the west and the gentler east dips further bear out this supposition. The Burnett fault was overthrust from the east. Pressure undoubtedly developed from the southwest also. This is shown by the overthrust faults on the west side of the main anticlinal axis, all of which indicate thrusting from the southwest. This faulting was probably not simultaneously effected, but seems to have been done serially or in stages. The normal faulting may also be the expression of this pressure but it undoubtedly represents the last stages of faulting. The north pitch of the whole field seems to indicate a structural depression between this field and the Green River district of King County. Whatever may be the explanation of this basin, the forces acting to produce it have exerted a marked influence in determining the structure of the field under discussion. All of these forces or components of the pressures undoubtedly acted to produce the complex structure described.

CHAPTER IV.

COAL.

STRATIGRAPHIC RELATIONS.

The coal seams already named are seen to occupy places throughout the entire length of the known local stratigraphic column, but the most important development is in the Carbonado formation. The Wilkeson formation is lacking in seams, while the Burnett, though containing the maximum thickness of section, has but few seams of commercial importance. The Melmont-Fairfax series of sediments contains many seams but these are of limited commercial importance at present.

Within the belt of sedimentaries exposed in the Pierce County field coal seams may be said to be present everywhere, but it must not be inferred from this that they are workable seams, nor that some of the workable seams are profitable seams. Although the igneous margins of the field will limit the area of operations it is probable that the future extension of many of the seams will be carried on in the concealed areas now covered by glacial material. This extension will be carried on by underground development rather than by new surface plants because of the greater opportunity for careful prospecting and the savings to be effected in the problems of mining, transportation and drainage.

DESCRIPTIVE DETAILS OF COAL.

All the Pierce County coal is bituminous, but the composition varies between wide limits in the same seam, and between associated seams as well as seams in the different formations represented. Some anthracite has been found, but as it represents local metamorphism near the contacts with igneous dikes it will not be further considered.

The upper coal seams, those of the Burnett formation, carry higher ash than those of the Carbonado or the underlying formation. The amount of ash progressively decreases as can be seen from the tables of analyses in the appendix. The per cent

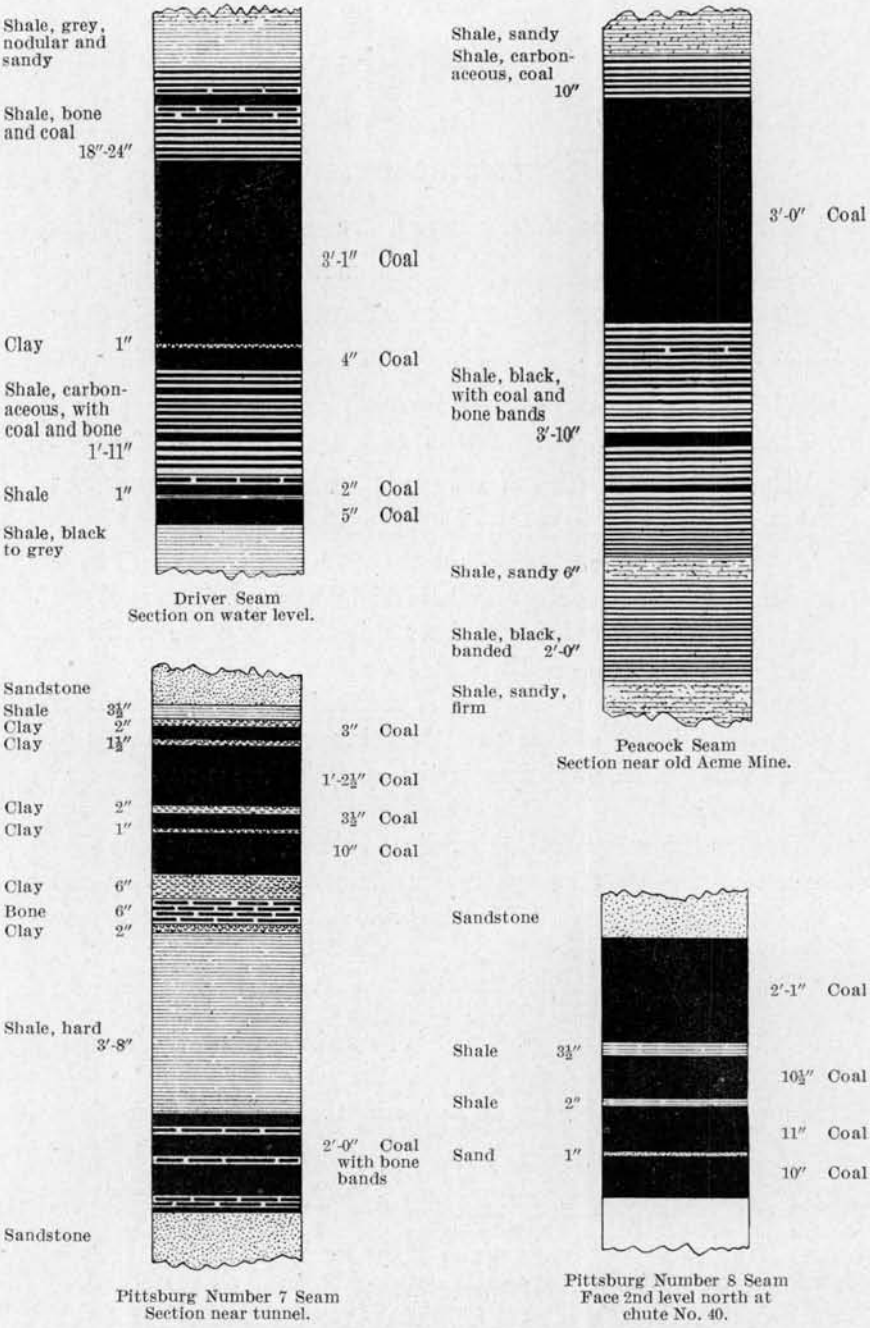


Fig. 1. CROSS-SECTIONS OF COAL SEAMS AT SPIKETON.

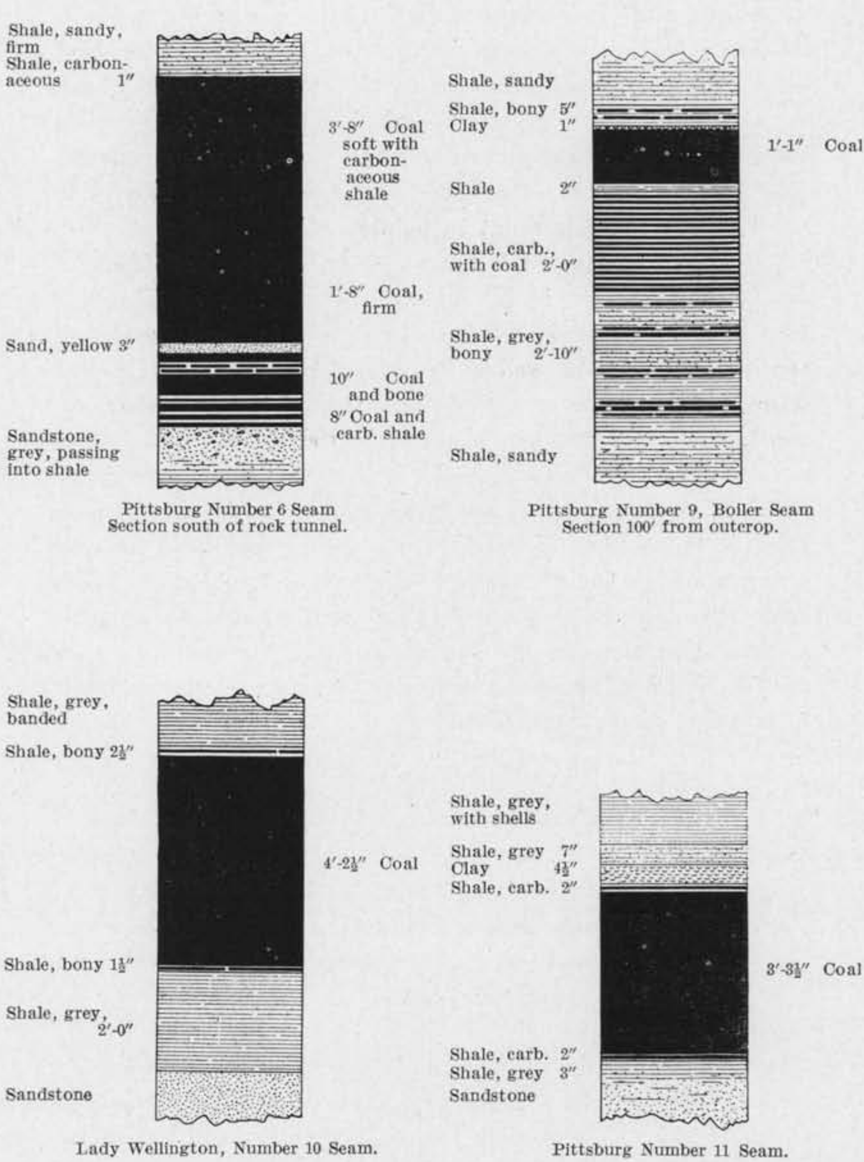


Fig. 2. CROSS-SECTIONS OF COAL SEAMS AT SPIKETON.

of volatile matter decreases and the fixed carbon increases as the lower seams are approached. In a general way the heat values increase in accordance with the variations noted above, but this increase is not so well marked as the variations in ash, volatile and fixed carbon contents. No comparison can be made of the analyses of any one seam as these are subject to many variations from point to point.

Typical sections of the seams now worked in the field under discussion are given in figures 1 to 15. Study of these will show the differences in total thickness and in the thickness of benches or bands, as well as the character of the coal in the seams. During the period of deposition of the coal beds, the oscillating levels and the changes in the materials deposited were of very pronounced extent. The result is seen first in the varying intervals between seams; second, in the total thickness; third, in the position of bands of impurities; fourth, in the constituents of the coaly matter. Add to these the changes which have taken place during the folding and faulting of this great accumulation of sediments and the result is the seams as they are found today, sometimes perfectly firm and regular and uniform, other times squeezed and crushed and possessing no coherence.

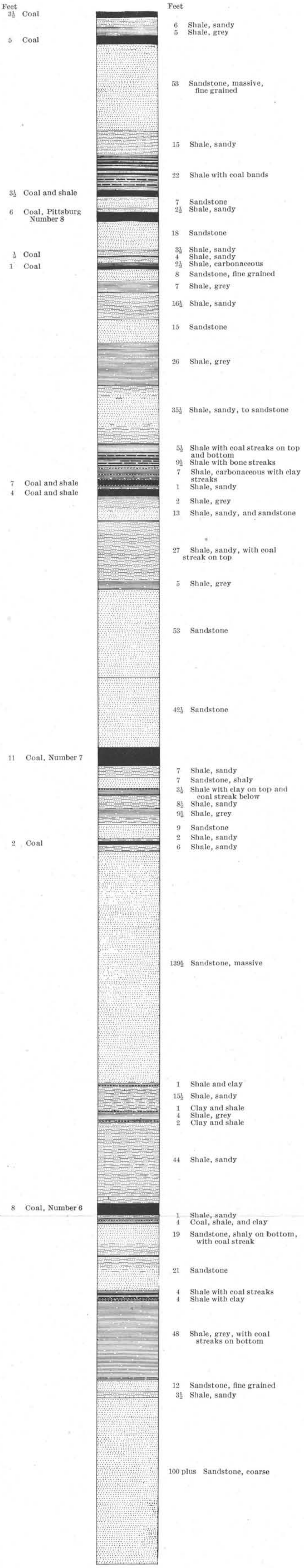
QUALITY OF COAL.

For purposes of classification, the material of the coal seams may be divided as follows:

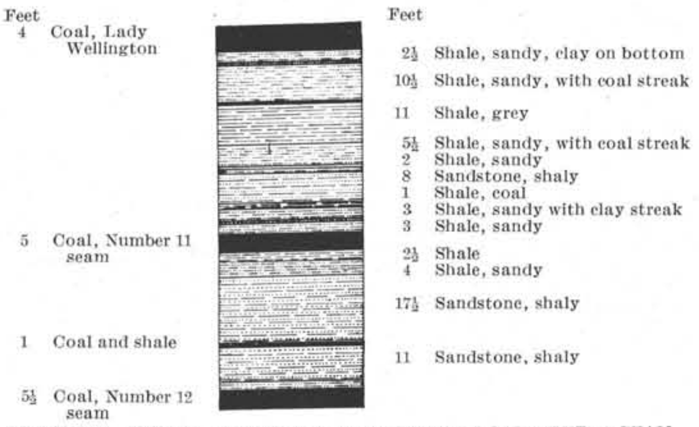
(a) Pure coal,
(b) Bony coal,
(c) Bone,
(d) Carbonaceous shale.

The pure coal is characteristically black, usually with a vitreous lustre, and is massive and dense, breaking into irregular small pieces. The streak varies from black to a brownish or greyish-black. The specific gravity is 1.3 to 1.35 and in the pure coal the ash is very low, from 6 to 8 per cent. Sulphur in all the coals is low.

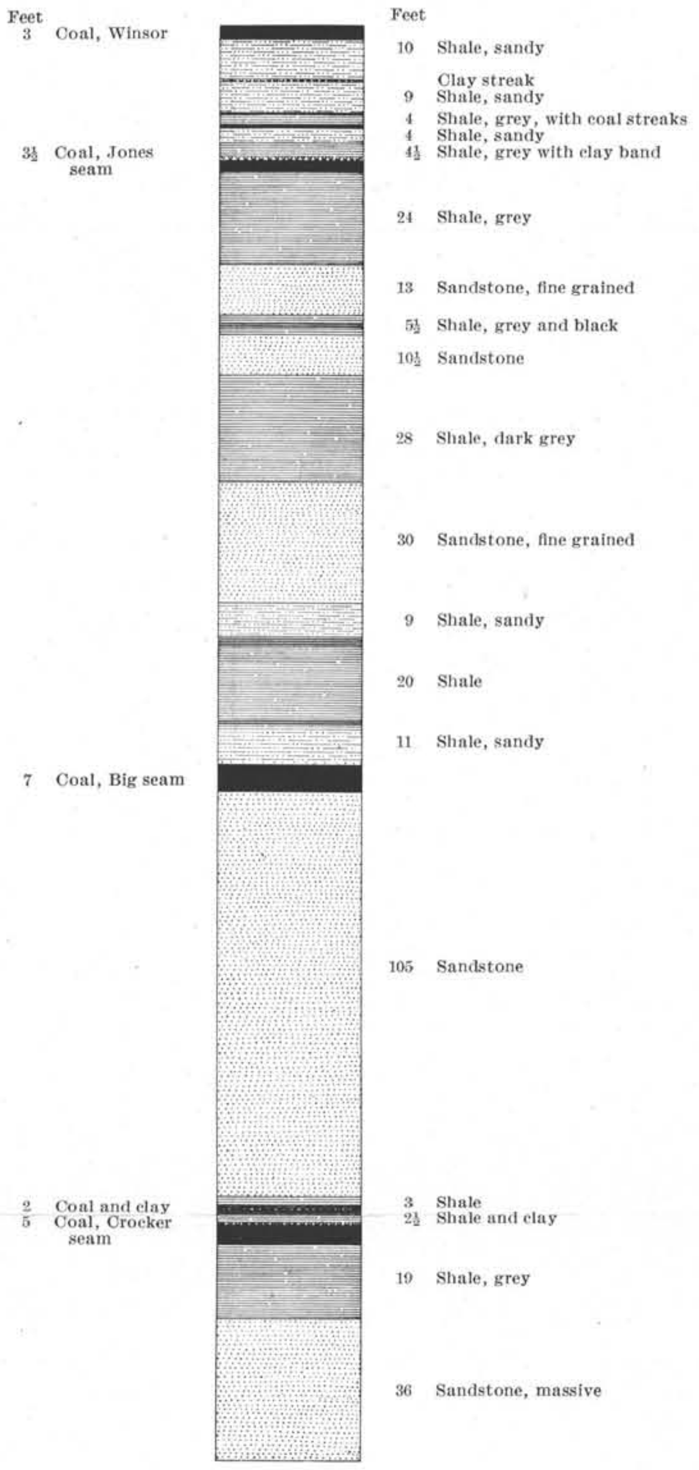
The bony coal is duller and more blocky than the pure coal and shows alternating thin layers of bright lustrous coal and



SPIKETON. ROCK TUNNEL FROM PITTSBURG NUMBER 8.



SPIKETON. TUNNEL FROM LADY WELLINGTON TO NUMBER 12 SEAM.

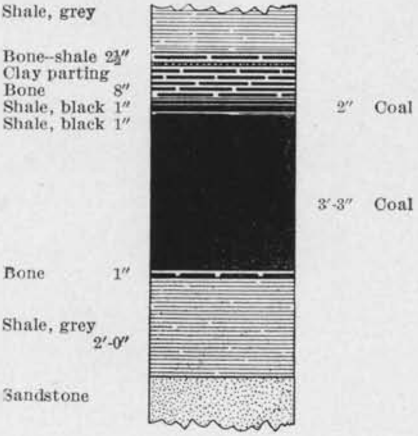


SOUTH WILLIS. TUNNEL EAST FROM WINSOR SEAM.

Columnar sections of Burnett formation exposed in rock tunnels at Spiketon and South Willis.

the duller layers of darker coal. This coal is characterized by higher specific gravity, 1.35 to 1.45, and higher ash, 12 to 20 per cent, and may be said to be the typical form in which the coal exists.

Bone is a variable term applied to grey or black shale carrying interlaminated streaks of coal or bony coal which could be separated by fine crushing. It is usually very hard and has a specific gravity ranging from 1.45 to 1.50 and an ash content of 26 to 30 per cent.



Pittsburg Number 12 Seam.

Fig. 3. CROSS-SECTION OF COAL SEAM AT SPIKETON.

The carbonaceous shale is a black or greyish black shale which may form the thin partings or "leaders" between the coal benches or it may exist as thick bands. In the form of partings it is usually hard and persistent. At other times it is soft and foliated and crumbles away very readily, forming the "mining." The specific gravity of the hard black shale is 2 to 2.2 and it contains fifty per cent ash.

In addition to the above constituents, yellow or white clay bands, or thin stringers of sandstone are found in the seams. In some cases they are very characteristic; in others, they are purely local. All of the normal constituents of the coal beds noted above sometimes grade into each other within the width of a working face and a great deal of the "personal equation" enters into the measurement and description of such sections.

The grading of the coal beds into their commercial uses is not altogether satisfactory because the factor of washing and preparation enters. However it may be said that the seams of the Burnett formation are adapted to steam generation but are not suitable for gas or coke manufacture; the better seams in the

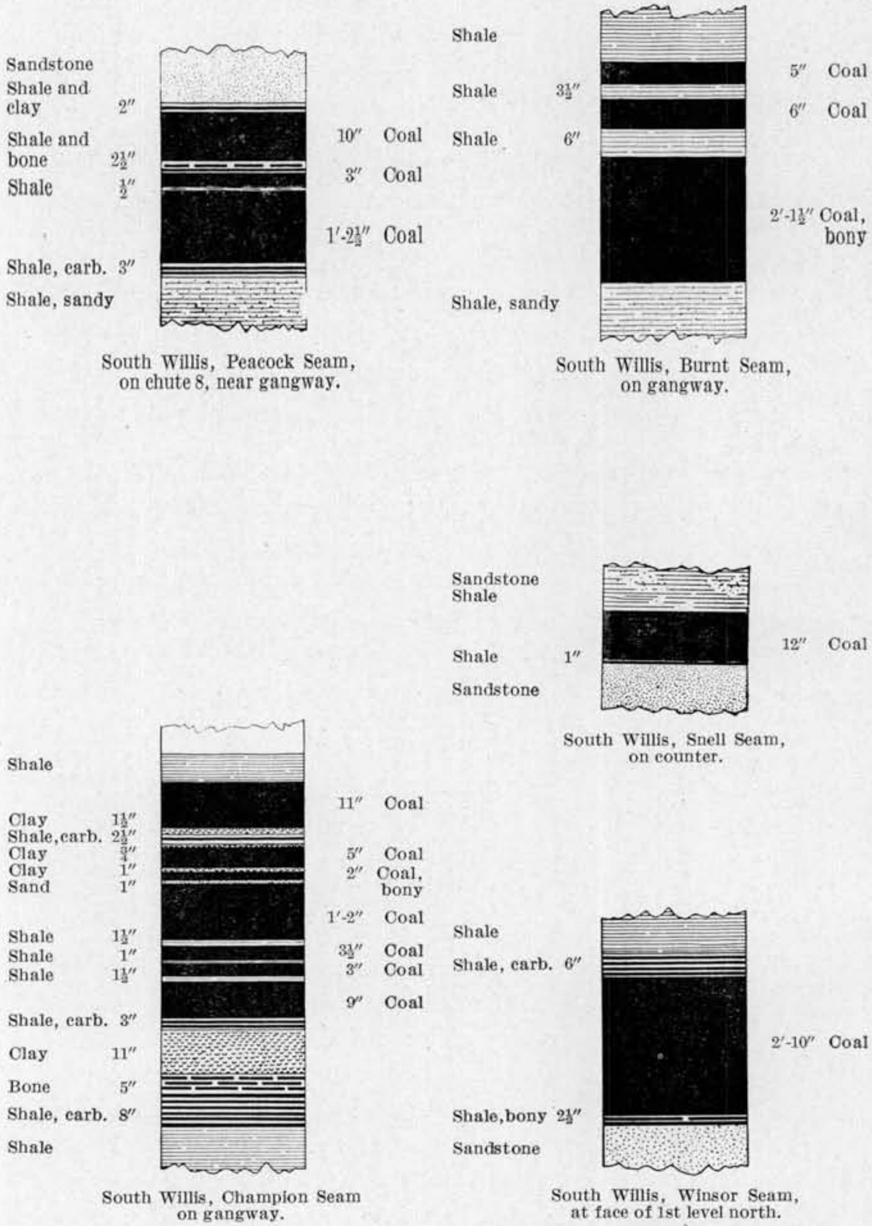


Fig. 4. CROSS-SECTIONS OF COAL SEAMS AT SOUTH WILLIS.

Carbonado formation excel in gas and coking properties, while the other washed products are good domestic and steam coals; and the formation below the Carbonado is best suited for coking coals. Some blacksmith coal is prepared from the lower seams.

QUANTITY OF COAL.

The quantity of coal in Pierce County has never been accurately determined, nor can even a reasonably accurate estimate be made. The structural conditions involving steep dips and faults, the variable thicknesses and extent of seams, the intrusion of igneous rocks, and the cover of forest and glacial materials introduce factors which are largely indeterminate. The table of production in the Appendix summarizes the operations during the known history of the field. Within the limits of the property of any of the present producing mines an approximate estimate of tonnage can be made on the basis of the development work, but this is felt to be outside of the scope of this bulletin and it has not been attempted.

CHARACTER OF COAL.

The quality of the coal and some of its characteristics have already been described and will be further discussed under the questions of mining and preparing the coal. For a detailed description of the character of Washington coals the reader is referred to "Coals of the State of Washington" by E. Eggleston Smith, Bulletin, U. S. Geological Survey, No. 474, 1911. A table of analyses of Pierce County coals, taken from that bulletin, is given in the appendix to this volume.

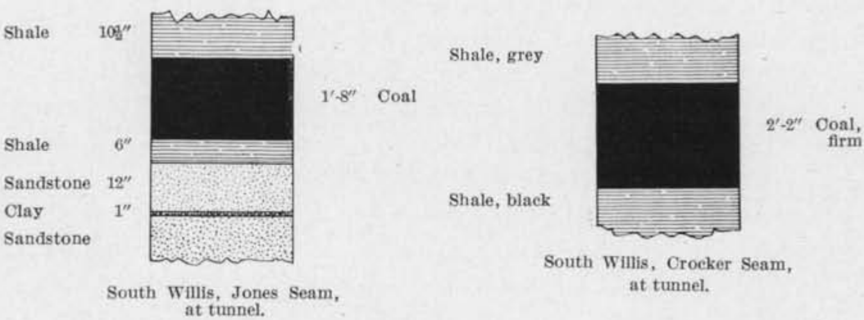


Fig. 5. CROSS-SECTIONS OF COAL SEAMS AT SOUTH WILLIS.

CHAPTER V.

MINING INDUSTRY.

HISTORY OF MINING.

Coal was discovered in the canyon of Carbon River about 1862 or 1863. The first coal location, however, was not made until 1874 when the Flett Brothers and their brother-in-law, Gale, opened a claim on Flett or Gale Creek above the present town of Wilkeson. A wagon road was constructed from South Prairie to the mine and a number of tons of coal hauled to Tacoma. At this time, 1873, the Northern Pacific Railway had been built from Kalama to Tacoma, but the road across the Cascades had not been begun. The coal discoveries were near the line across the mountains which would be adopted should Tacoma be its terminus. In view of this an engineer, Benjamin Fallows, of Pittsburg, was sent out to investigate the coal prospects and he reported favorably. Surveys were made for a road in the fall of 1875 and on May 6, 1876, the route was formally adopted and a map filed with the Interior Department. This portion of the Cascade division, which was generally known as the Puyallup Branch, was built in 1876 from Tacoma to the coal field at Wilkeson, a distance of 30 miles, and a short spur was afterward (1880) built to Carbonado to reach a mine sold by the Northern Pacific to the Central Pacific Railroad. The town at the coal mines was by vote of the Board of Directors of the railroad named Wilkeson, in compliment to the secretary of the company, Samuel Wilkeson, who made a trip overland to the coast with the first engineers sent out and who wrote a report on this trip, known as "Wilkeson's Notes."

The original Wilkeson mine was abandoned after two or three years' operation and in 1879 the present Wilkeson mine on the western dip was opened by the railroad company. About the same time the seams on the eastern dip were opened by the Tacoma Coal and Coke Company. No records of the productions of these mines are available before the year 1884

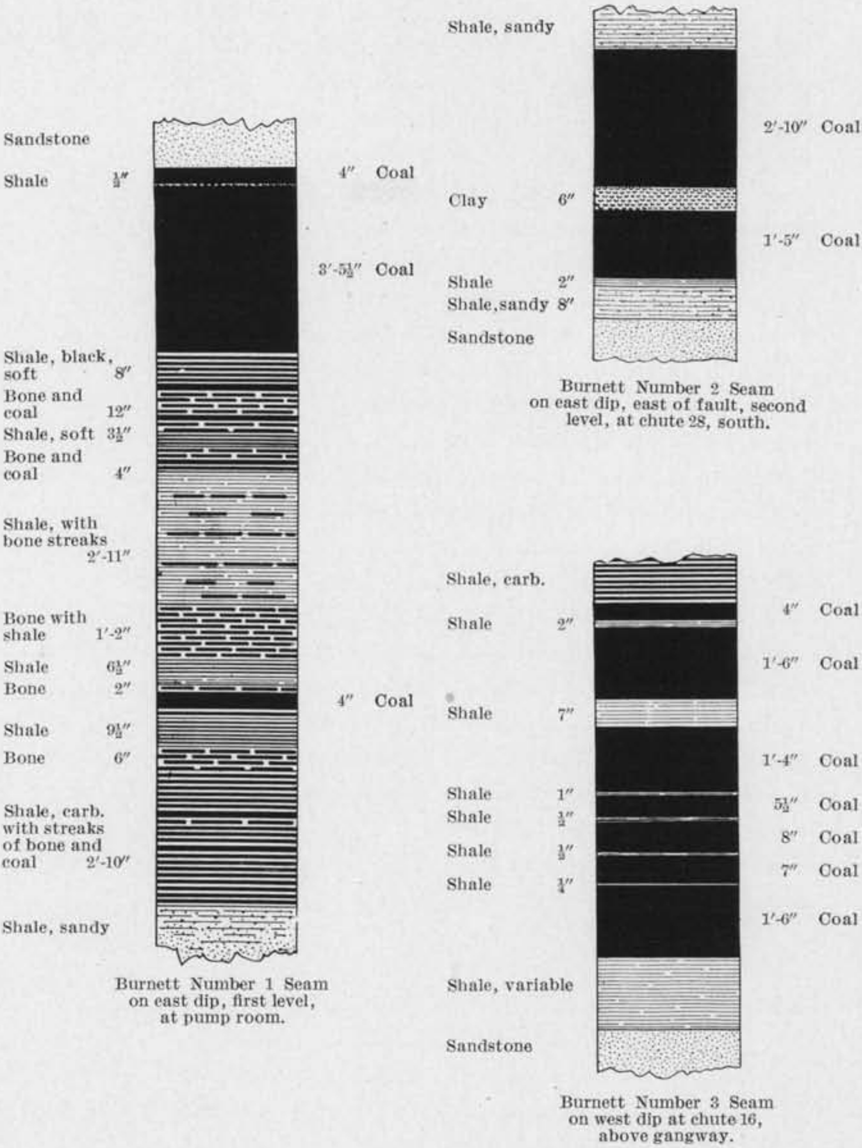
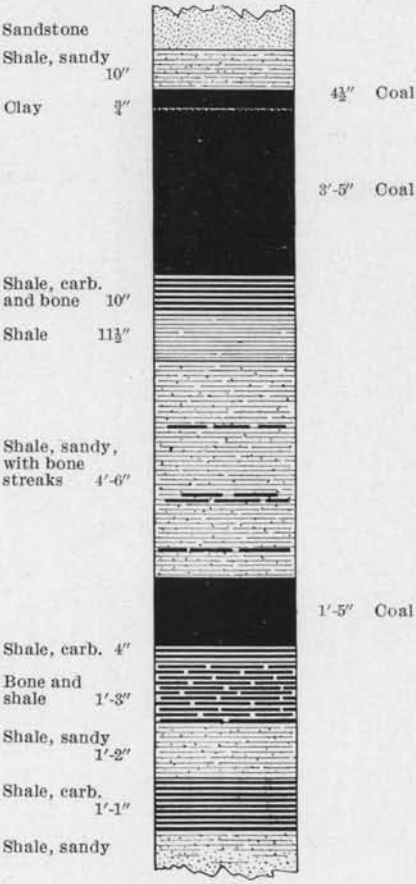


Fig. 6. CROSS-SECTIONS OF COAL SEAMS AT BURNETT.

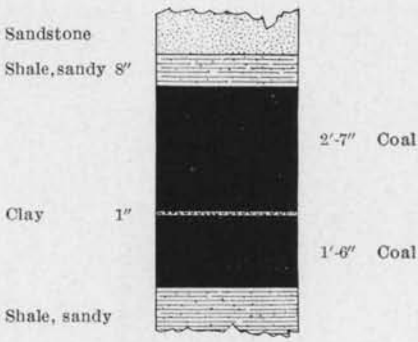
or 1885. It seems probable that some of the mines first opened were abandoned or else worked very little until 1885. We find records in the Territorial Mine Inspector's Report for 1887 giving the productions for the years 1885, 1886, 1887 for the Tacoma Coal & Coke Company, but none for the Wilkeson mine until 1888-1889. The mine opened on the eastern dip was known as the Smith Vein or the present East 3 seam. It was worked until 1893 and then shut down, to be later reopened by rock tunnels from the seams on the west dip worked by the Wilkeson Coal & Coke Company, which was organized in 1888. It secured control of the seams on both the east and west dips, although at first it leased the west dip seams on royalty from the Northern Pacific Railway Company. The first company in the state to manufacture coke was the Tacoma Coal and Coke Company in 1884. Its ovens were built at the end of 1885 and ten of them were in operation in 1886. In 1888, thirty ovens were running, and today one hundred are in use. [PLATES XXII and XXVII.]

The next property in the Wilkeson district to be operated was the Gale Creek mines. These were first opened on the Hill and Driver prospects about 1898 and a co-operative company, known as the Miners' Coal and Coke Company, was started in 1899. This was succeeded in 1900 by the Gale Creek Coal Company. The Brier Hill property was opened in 1907 and reported a production of 800 tons in that year. The Hi Davis mine was opened in 1909 to supply fuel for the light and water plant of the town.

The mine at Burnett was opened by the South Prairie Coal Company in 1881, by a water level drift on No. 1 seam. In 1894 search was begun for the underlying seams and in 1895 No. 2 seam on the east dip was found. Subsequent rock tunnels tapped the same seams west of the fault and No. 3 seam, but the exact relationship was not worked out until later. In 1906 the control of the South Prairie Coal Company was transferred to the Pacific Coast Coal Company and the active management of Mr. C. H. Burnett, after whom the mine was named and who opened the property in 1881, ceased.



Burnett Number 1 Seam
on west dip, at chute 2,
above gangway.



Burnett Number 2 Seam
on west dip, west of fault,
at chute 1, south of tunnel.

Fig. 7. CROSS-SECTIONS OF COAL SEAMS AT BURNETT.

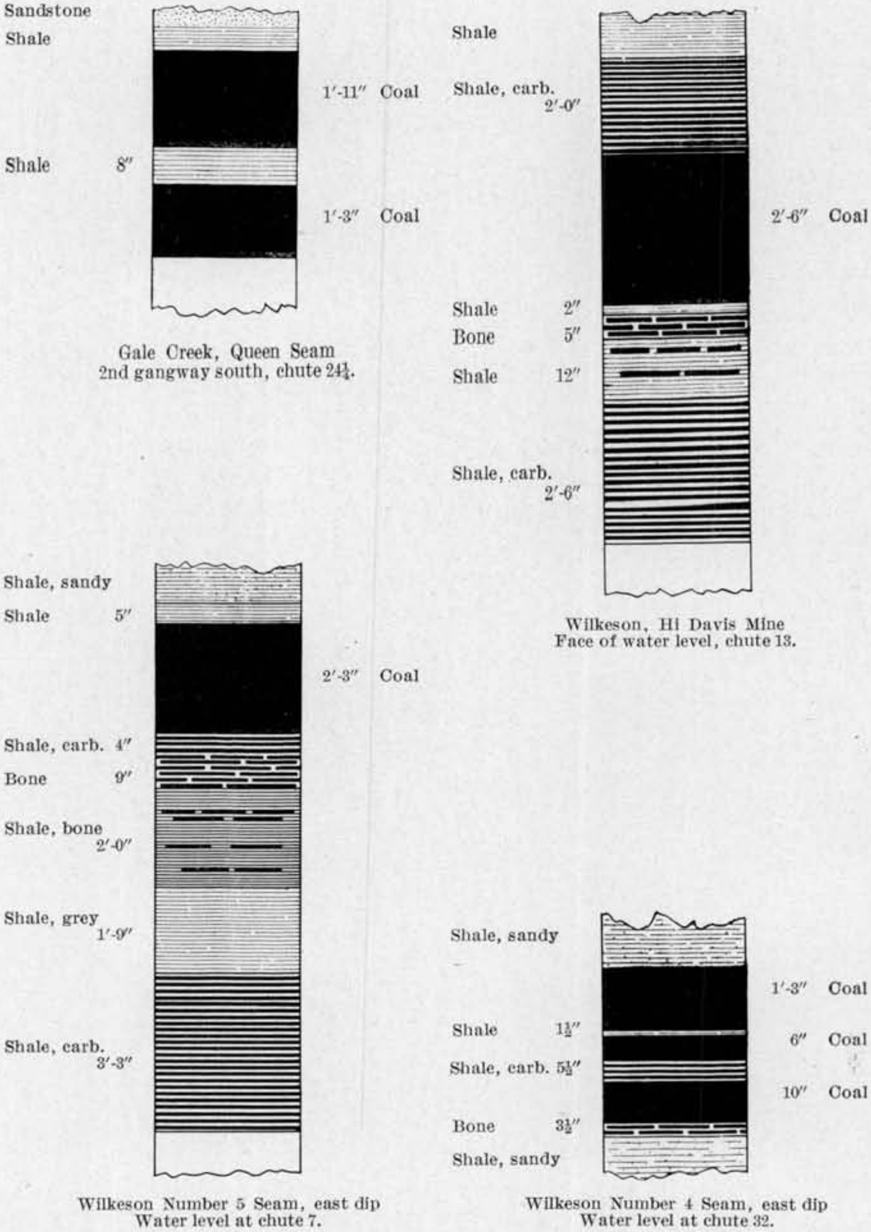
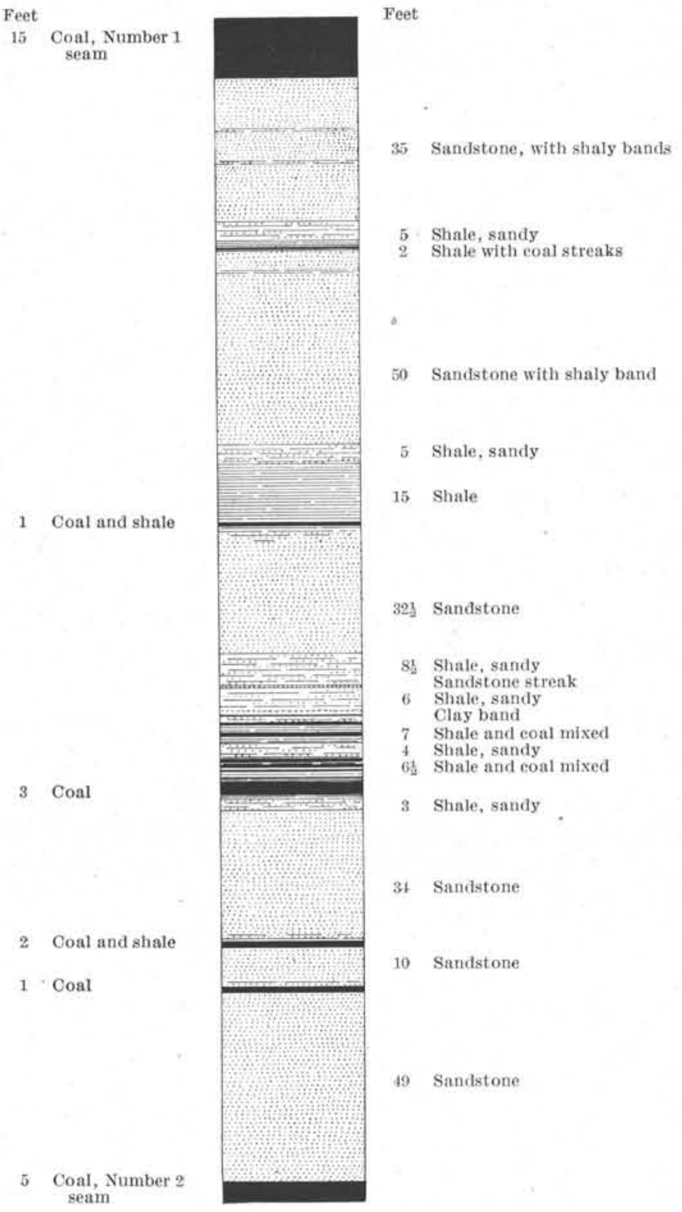
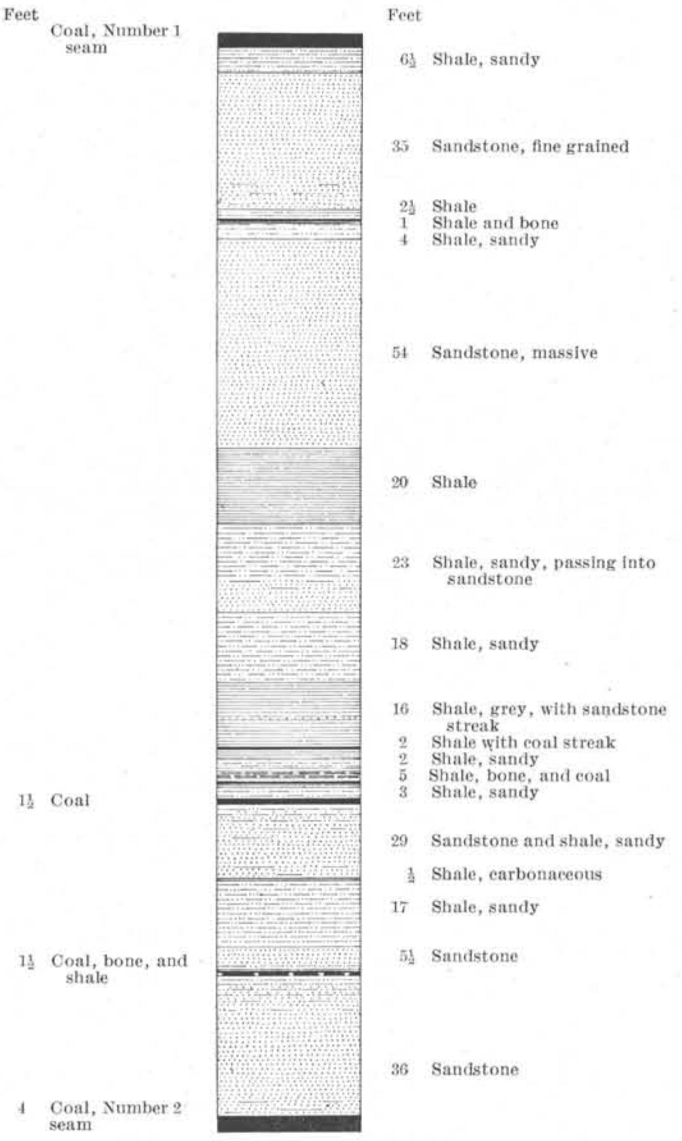


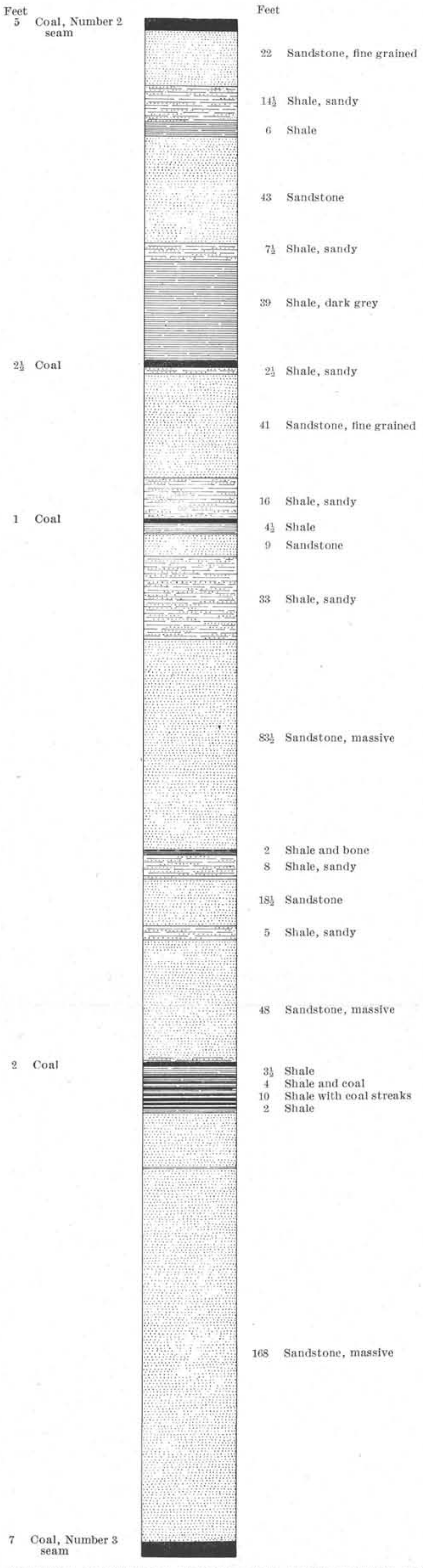
Fig. 8. CROSS-SECTIONS OF COAL SEAMS AT GALE CREEK AND WILKESON.



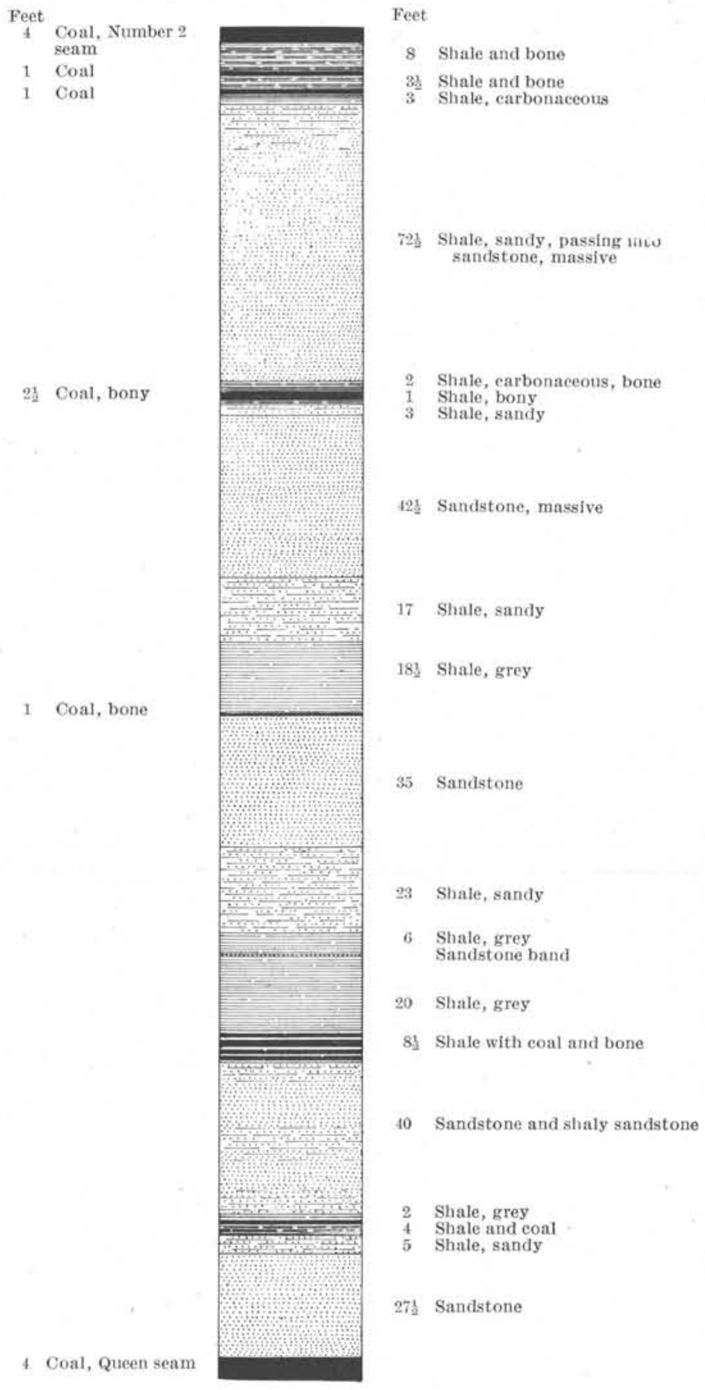
BURNETT. SECTION "A", TUNNEL WEST FROM NUMBER 1 SEAM, EAST DIP, FIRST LEVEL, TO NUMBER 2 SEAM.



BURNETT. SECTION "C", TUNNEL EAST FROM NUMBER 1 WEST DIP TO NUMBER 2 WEST DIP.



BURNETT. SECTION "B", SECOND LEVEL FROM NUMBER 2 SEAM, EAST OF FAULT, WEST TO NUMBER 3 SEAM.



GALE CREEK. SECTION "D" ON TUNNEL FROM NUMBER 2 TO QUEEN SEAM.

The properties at Carbonado, known as the Carbon Hill Coal Company, were probably the first in Pierce County to be opened, as the canyon of Carbon River has exposed the seams much more clearly than in any other part of the field. No record was kept of any mining until 1885. It is known that the mines were shipping in 1880, the branch line from Wilkeson having been extended to Carbonado. The coal mined in the early days was chiefly used in California by the Central Pacific and the Southern Pacific railroads, and for a long time thereafter the principal market for Carbonado coal was in California and Oregon. In 1886 the mines were closed for a time on account of labor troubles. In 1887 steam locomotives were introduced for mine and outside transportation. No. 1 mine was the first mine in the state to be lighted by electricity, 1895. The seams to be first developed were the Wingate, Miller, Number 4, South 7, North 1, and North 2. The Carbon Hill mines are the largest in the state with the one exception of the Northwestern Improvement Company's Roslyn mines. For several years, or up to the time that the latter properties were well developed, the Carbonado property had the highest record of individual tonnage. Coke ovens were installed in 1911 and in 1912 coke was first produced at this property.

The Northwest Improvement Company, operating at Melmont, began prospecting in 1900 and in 1902 shipped coal.

In 1896 work was begun on the properties in section 26 by the Western American Company and a railroad line located from Carbonado. The construction of this road and the opening of the mine were carried on in 1897 and 1898 and the mine became a producer in 1900. The property was first operated with white, then colored, and finally Japanese labor, and seemed to have considerable difficulty in getting started. In 1900 twenty-five coke ovens had been built and in 1901 this number was increased by thirty-five more. The Tacoma Smelting Company secured the property in 1907 and worked it until 1911, at which time work was started on a new mine in section 34, now known as the Fairfax Mine, Inc.

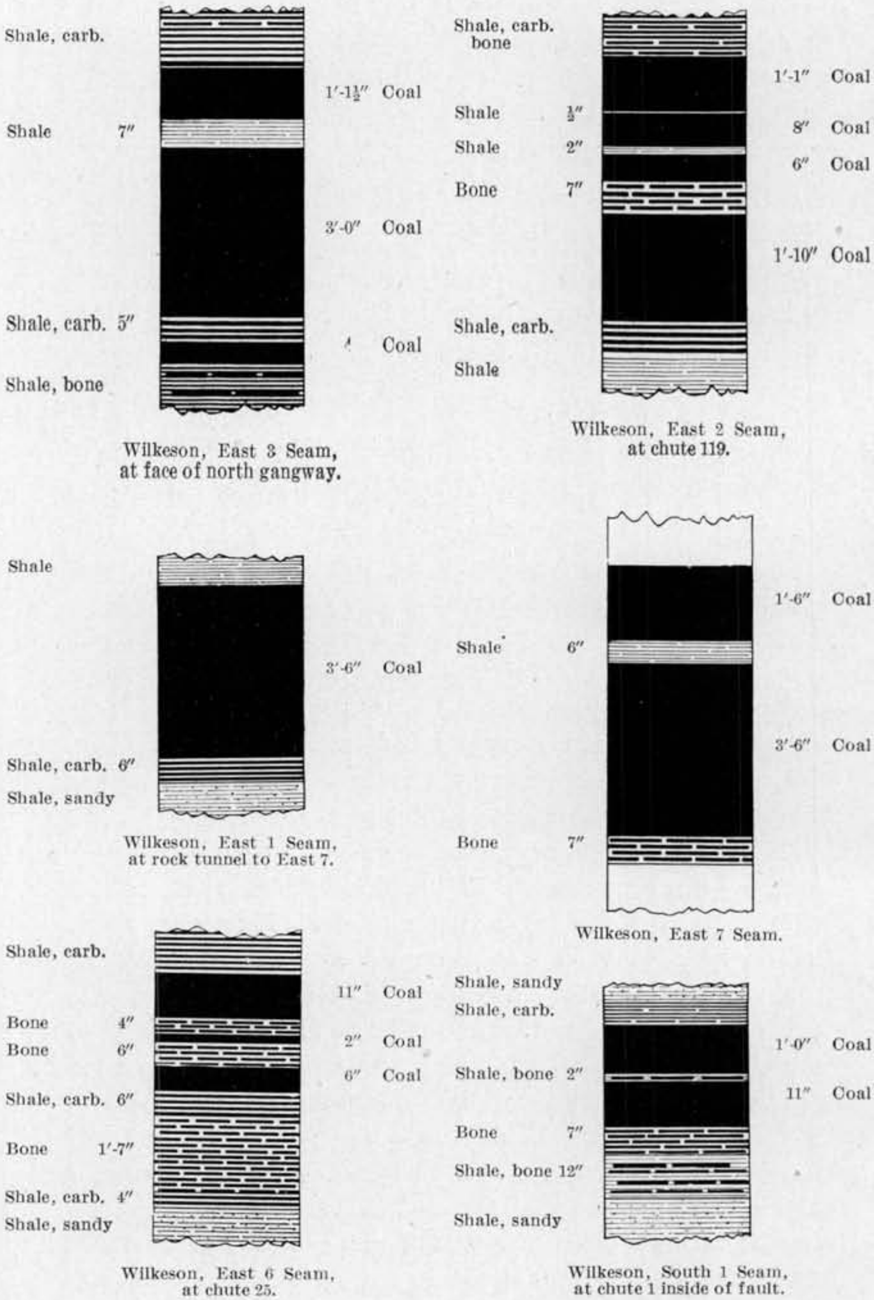


Fig. 9. CROSS-SECTIONS OF COAL SEAMS AT WILKESON.

The Montezuma Mine on Evans Creek, one and one-half miles south of Fairfax, began to develop in 1901. In 1901 it had begun to produce coal and continued shipping intermittently until 1910, when the mine closed down. At present the mine is owned by the Montezuma Coal Company. This mine was one of the coke producers of the county with a battery of 25 ovens.

The Olympic Mining Company developed a small mine in section 36 along Carbon River, southeast of Fairfax, in 1901. Beyond driving a tunnel and shipping a few hundred tons of coal nothing further was done.

In the southern half of the field, south of the Puyallup River, very little actual mining has been done, although many prospects have been opened. George Otis Smith makes the statement that in 1875 a ton of coal from the Puyallup Valley was taken to San Francisco, but the field was practically abandoned in 1880. In 1904, the deposit near Ashford was opened up by the Mashell Coal and Coke Company and development work in driving rock tunnels was carried on during the next few years. In 1909, the mine shipped 655 tons. The production was considerably greater than this, but no record has been kept of the actual tonnage. The property is owned by the Western Steel Corporation.

The mines at Pittsburg now operated by the American Coal Company have had a checkered career. [PLATE XXIII.] The first record of mining on these seams was in 1891, but the operations ceased in 1892. In 1892, the Acme Mine was opened and shipped coal until 1894. The Ouimette Mine, between the Acme and the Burnett mines, was opened in September, 1893, and shipped until 1896. Later, in 1903, this property was opened under the name of the Luzon Coal Company and then in 1908 by the Black Carbon Coal Company, but only a few thousand tons were mined and the property again closed. In 1900, 4,800 tons were mined by the Willis Coal Company, at Spiketon (Pittsburg), but it was not until 1907 that the present development of these mines began. Since then they have been steady shippers.

The southward extension of the Pittsburg seams at South Willis was first developed about 1902. Twenty-five coke ovens were built. The Gale Creek Company, operating at Wilkeson worked these properties and no separate record of production was kept. Seventeen hundred tons of coke was produced in 1904. In 1909 the Commonwealth Coal Company acquired the properties, which were later transferred to the American Coal Company, operating at Spiketon.

In 1904 the Pacific Coal and Oil Wells Company opened a mine in section 26, east of Wilkeson, and erected bunkers and a tram to the railroad. In 1905 they produced 2,400 tons of blacksmith coal and maintained a small production for two years more, but in 1907 the mine was closed.

In the territory south of the Wilkeson mines, a new company known as the Pacific Northwest Coal Company has recently acquired leases on the southward extension of some of the east Wilkeson and underlying coal seams in that portion of the field indicated in the earlier parts of this report as the eastern Wilkeson basin. This company has done considerable surveying and prospecting but no actual operation has yet been attempted.

ACTIVE MINES IN 1913.

The names of operators and mines from 1887 to date are given in the production table. It will be seen that some of the properties have suffered many changes of ownership while others have been under practically one management during their entire history. In 1913 nine companies were producing coal. Of these eight were active producers and one was simply continuing development work. Three companies produced coke.

The mines of the American Coal Company are located at Spiketon. Three seams are being worked, Nos. 6, 8 and 10. This company leases the properties at South Willis to the South Willis Coal Company, whose operations are mainly on the Winsor seam. The Pacific Coast Company operates at Burnett on three seams, but all the coal is brought to the surface through one opening. The Gale Creek Coal Mines Company and the

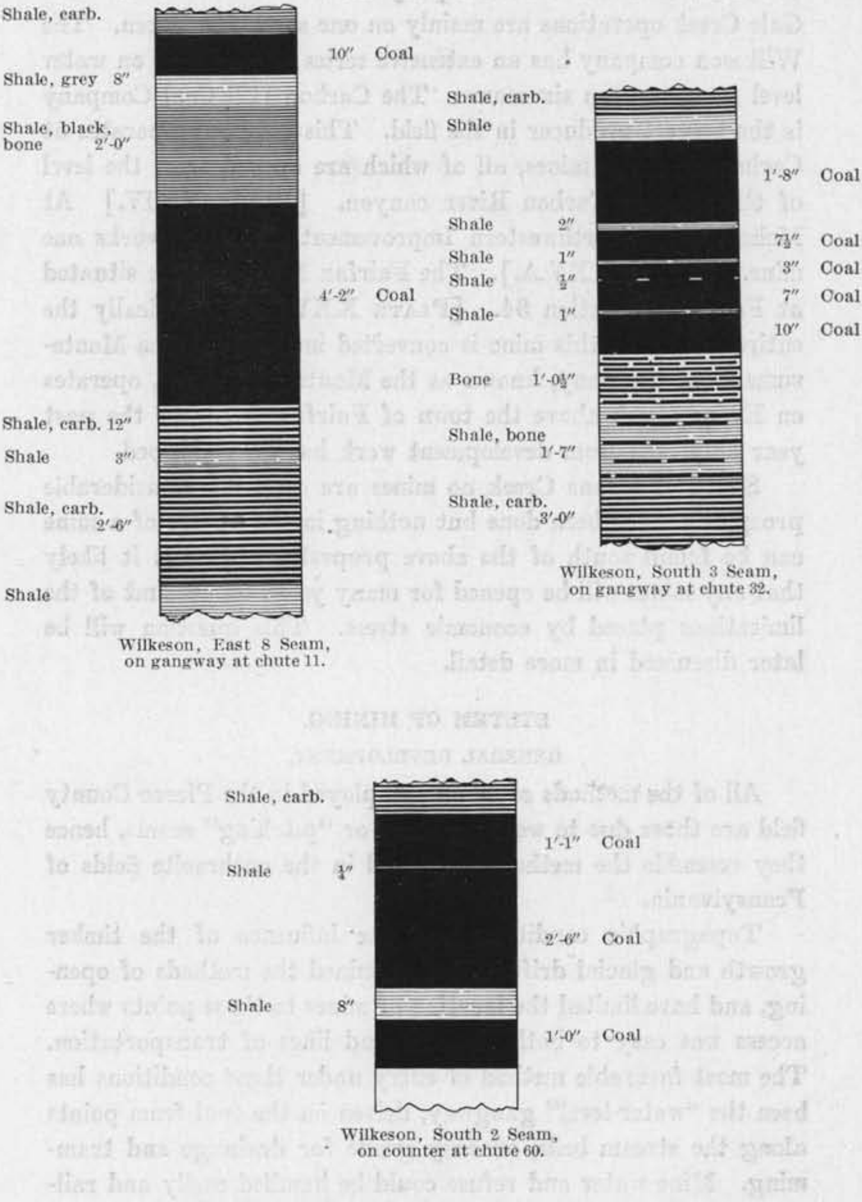


Fig. 10. CROSS-SECTIONS OF COAL SEAMS AT WILKESON.

Wilkeson Coal and Coke Company are both at Wilkeson. The Gale Creek operations are mainly on one seam, the Queen. The Wilkeson company has an extensive series of workings on water level gangways on six seams. The Carbon Hill Coal Company is the largest producer in the field. This company operates at Carbonado seven mines, all of which are opened from the level of the river in Carbon River canyon. [PLATE XXIV.] At Melmont, the Northwestern Improvement Company works one mine. [PLATE XXV A.]. The Fairfax Mine, Inc., is situated at Fairfax in section 34. [PLATE XXV B.] Practically the entire output of this mine is converted into coke. The Montezuma Coal Company, known as the Montezuma mines, operates on Evans Creek above the town of Fairfax. During the past year only coal from development work has been shipped.

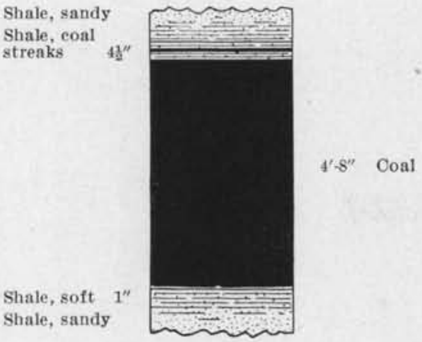
South of Evans Creek no mines are opened. Considerable prospecting has been done but nothing in the nature of a mine can be found south of the above properties. Nor is it likely that any mines will be opened for many years on account of the limitations placed by economic stress. This question will be later discussed in more detail.

SYSTEM OF MINING.

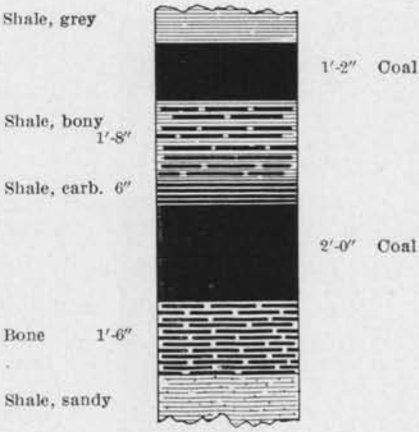
GENERAL DEVELOPMENT.

All of the methods of mining employed in the Pierce County field are those due to working steep or "pitching" seams, hence they resemble the methods employed in the anthracite fields of Pennsylvania.

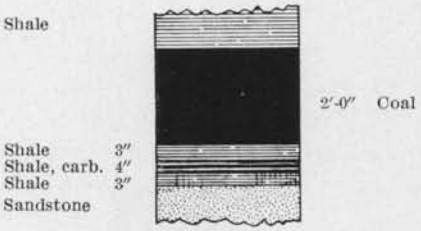
Topographic conditions and the influence of the timber growth and glacial drift have determined the methods of opening, and have limited the location of mines to those points where access was easy to both the coal and lines of transportation. The most favorable method of entry under these conditions has been the "water-level" gangway, driven on the coal from points along the stream beds, on easy grade for drainage and tramming. Mine water and refuse could be handled easily and railroad lines naturally follow stream drainage lines. A reasonable height or "lift" of coal, depending on the elevations of the hills



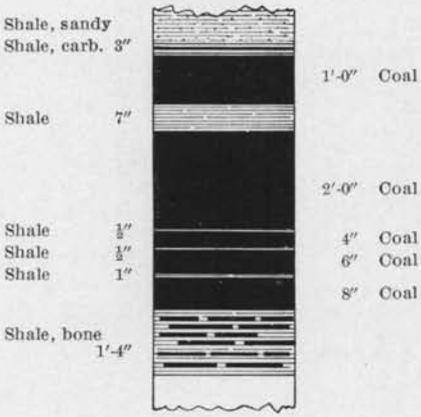
Carbonado, Wingate Seam,
No. 6 north on 4th level, chute 11.



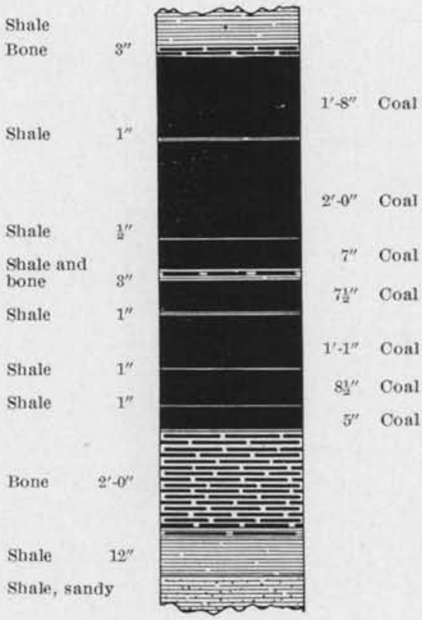
Carbonado, Bruiser Seam,
100′ south of rock tunnel, North 1.



Carbonado, Gem Seam,
South of North 1 tunnel.



Carbonado, Number 3 North,
(Wilkeson 3), beyond chute 42.



Carbonado, Number 1 North Seam,
on 2nd level, chute 44.

Fig. 11. CROSS-SECTIONS OF COAL SEAMS AT CARBONADO.

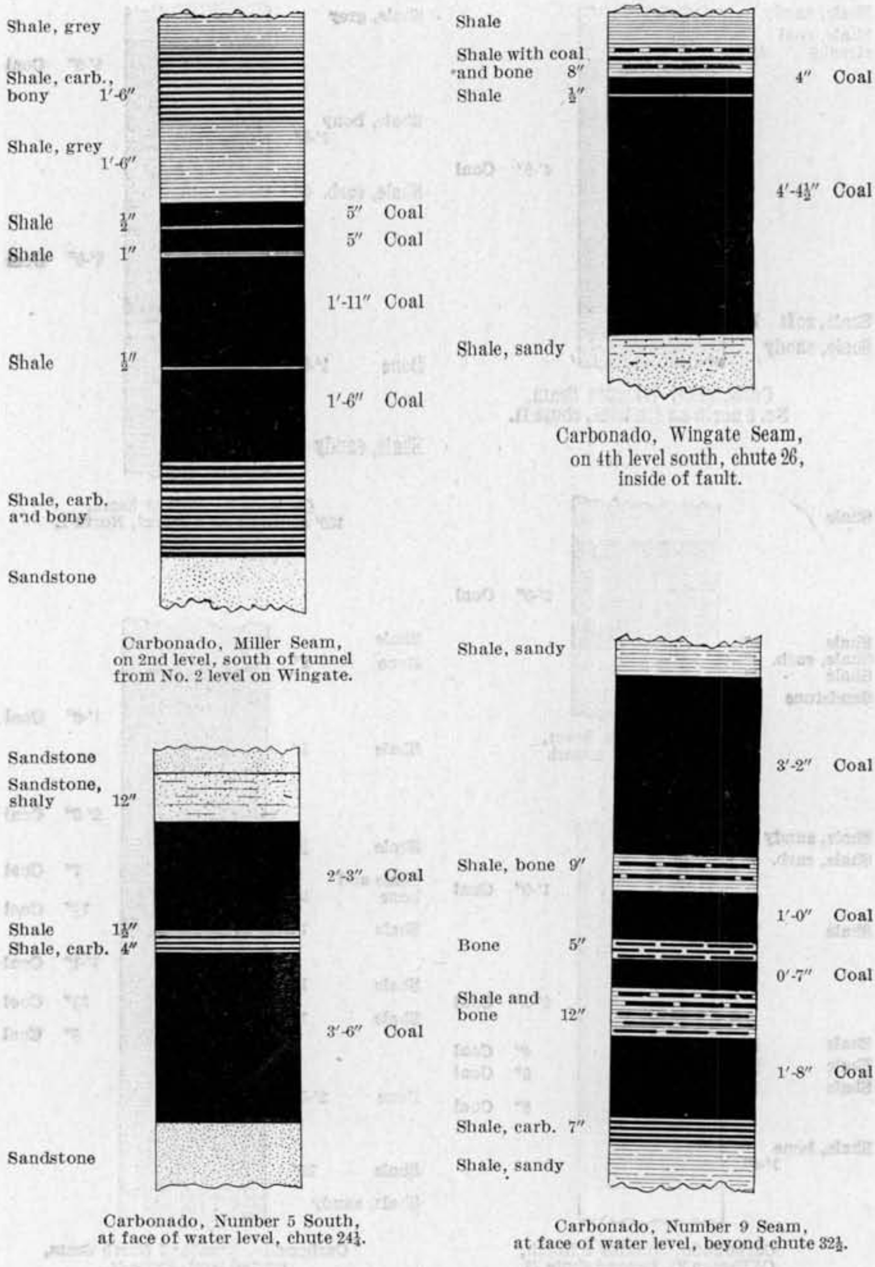
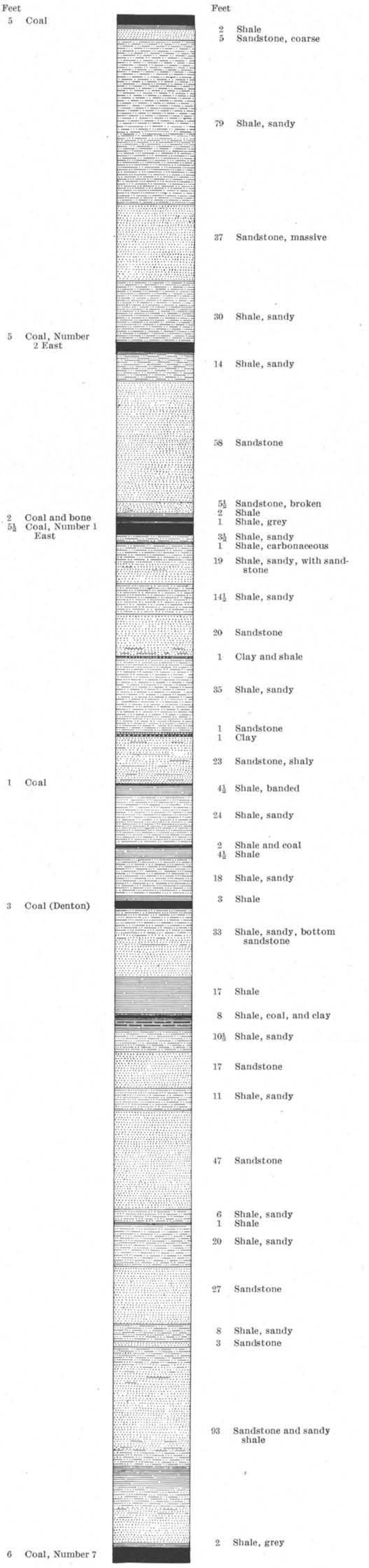
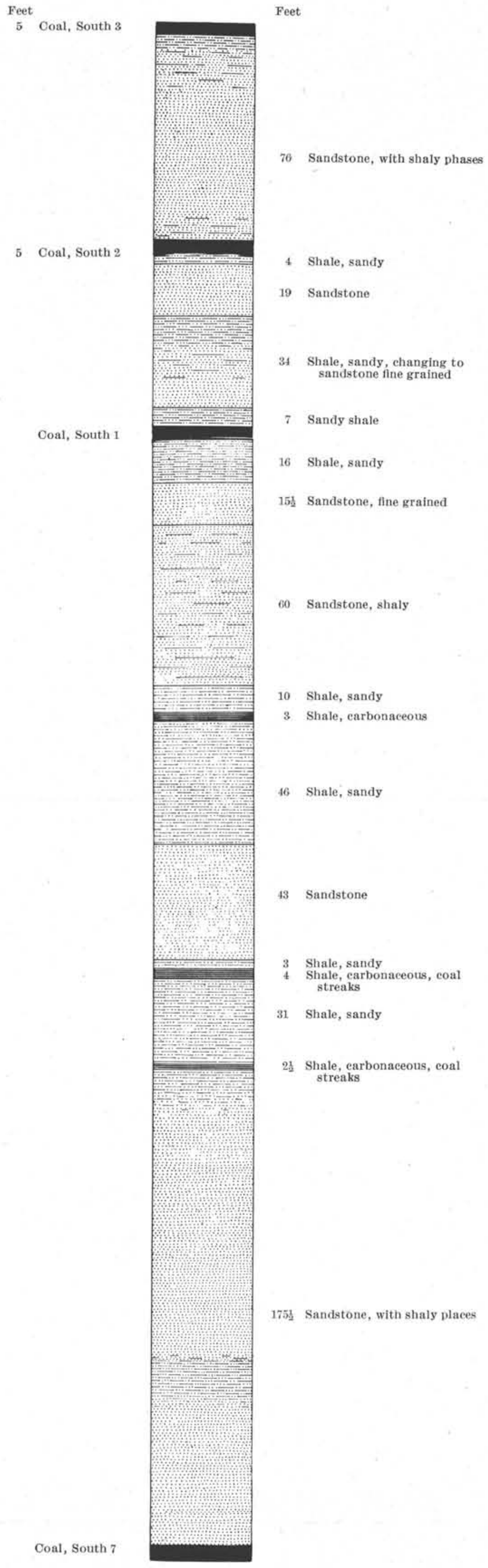


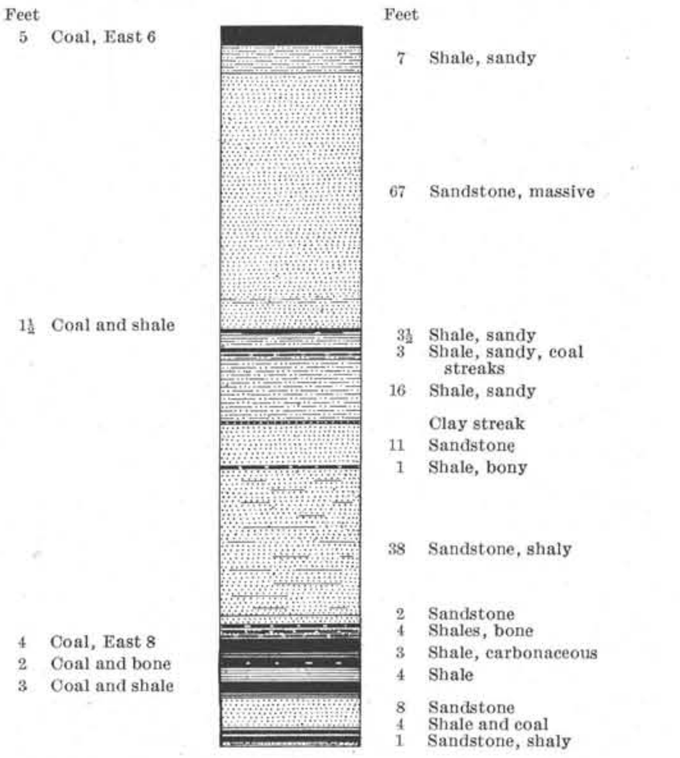
Fig. 12. CROSS-SECTIONS OF COAL SEAMS AT CARBONADO.



WILKESON. SECTIONS "E" AND "F" ON TUNNELS FROM EAST 3 TO EAST 7.



WILKESON. SECTION "J" ON TUNNEL FROM SOUTH 3 TO SOUTH 7.



WILKESON. SECTION "G" ON TUNNEL FROM EAST 6 TO EAST 8.

Columnar sections of Carbonado formation exposed in rock tunnels at Wilkeson.

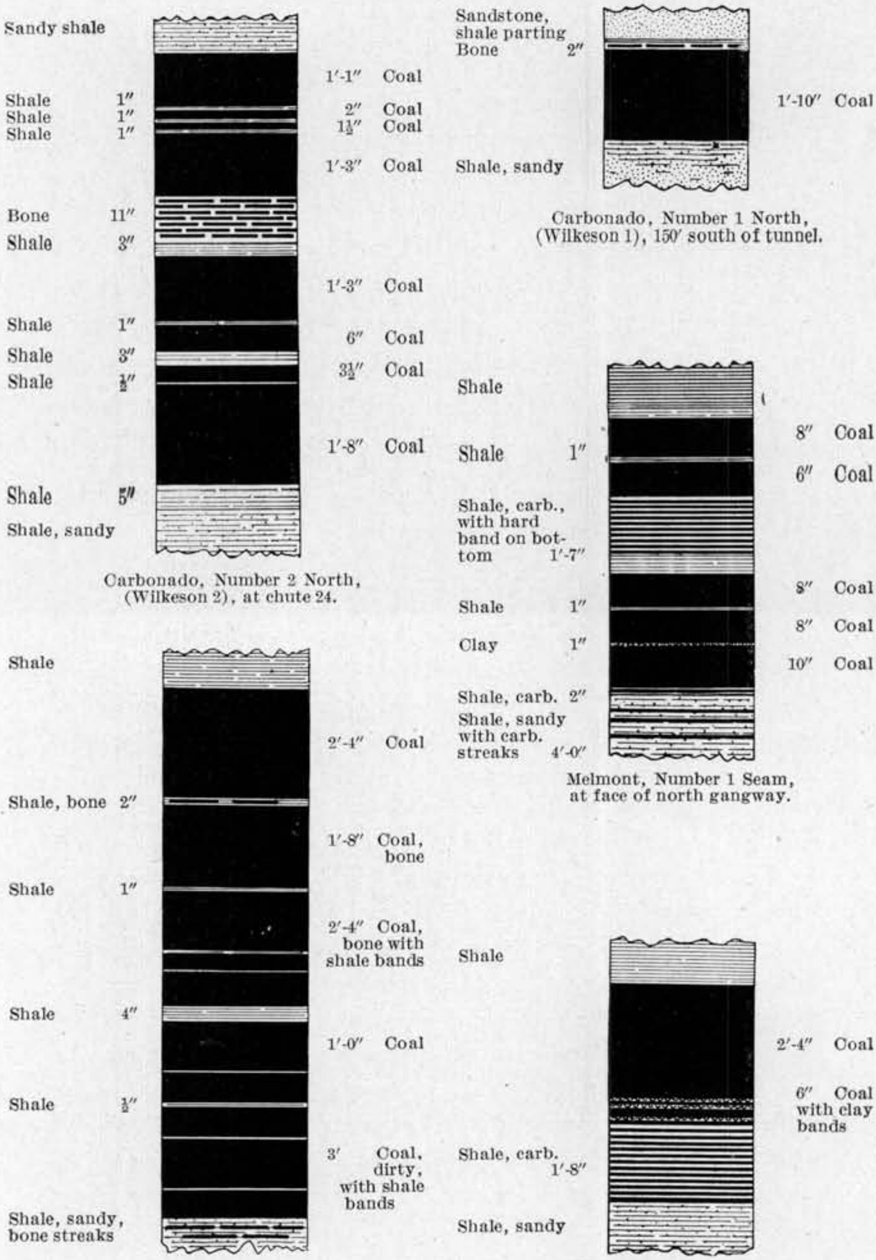
above the streams, was usually present. Hence the inevitable water level gangway or rock tunnel associated with the opening of practically every mine in Pierce County.

As development progressed the dip, rather than the rise, presented the territory for expansion and since shafts are practically out of the question, because of the conditions already enumerated, slopes on the coal to lower levels has been the later stage of development. In some parts of the field, new seams have been opened by rock tunnels cross-cutting the measures, the tunnels so driven serving as underground transportation ways to the older drift entries. No vertical hoisting shafts, therefore, are to be found in Pierce County. The Wilkeson mines are entirely on water-level; all of the other mines have some slope operations to the lower levels.

GENERAL MINING METHODS.

The methods of winning the coal are modifications of the room-and-pillar or chute-and-pillar systems of operation. Practically no longwall is at present used although it has been tried, and no mining machines are in use. The various modifications in the system of working are due to the character and thickness of the seam, the hardness of the enclosing strata, the dip, and the amount of cover.

Rooms or chutes are opened at right angles to the gangways, usually for the full height of coal between walls. In other cases the chute is only taken out for the height of good coal, leaving the rashing or top to be removed when the pillars are drawn. Under some conditions the chutes are driven across the dip at an angle in order to get an easier grade for the coal to travel. Paralleling the main gangway a counter is always driven leaving a stump pillar between of variable thickness which is cut by the narrow room or chute necks, or by traveling ways. Under the gravel cover at the surface, a top gangway from which air chutes are carried to the surface is driven which serves the double purpose of ventilation and tramway for timber which is dropped down from the surface. Crosscuts in the pillars are at a maximum interval of 60 feet.



Carbonado, Number 2 North, (Wilkeson 2), at chute 24.

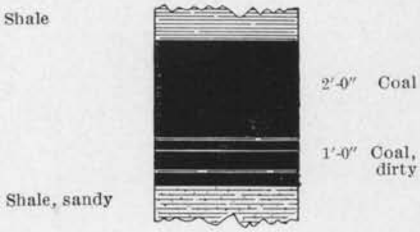
Carbonado, Number 1 North, (Wilkeson 1), 150' south of tunnel.

Melmont, Number 1 Seam, at face of north gangway.

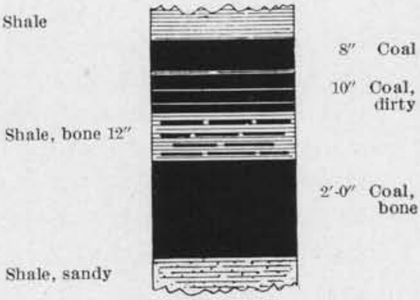
Melmont, Number 3 Seam, second level, north of slope at chute 80.

Melmont, Number 2½ Seam, north of rock tunnel.

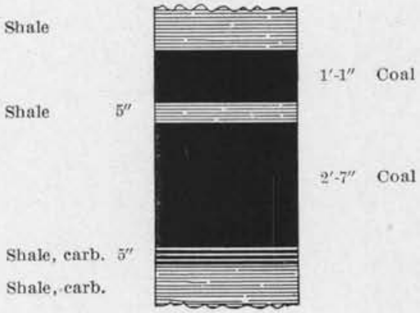
Fig. 13. CROSS-SECTIONS OF COAL SEAMS AT CARBONADO AND MELMONT.



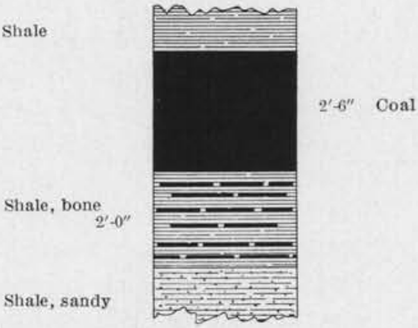
Melmont, Number 4½ Seam, south of rock tunnel.



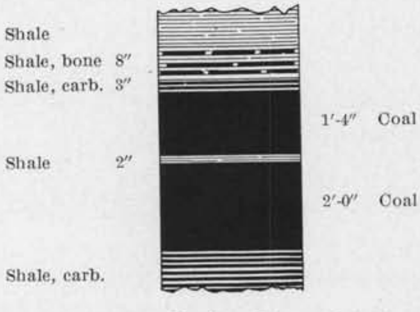
Melmont, Number 5 Seam, at chute 1.



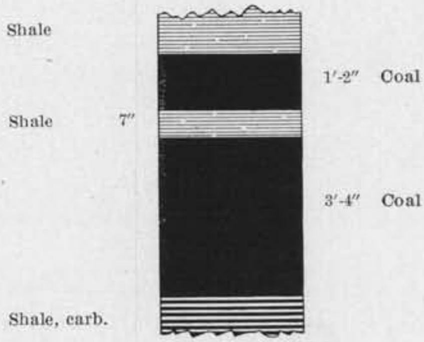
Montezuma, Number 1 Seam, chute 6.



Montezuma, Number 3 Seam, inside 1st rock tunnel.



Montezuma, Number 2 Seam, chute 41.



Montezuma, Number 4 Seam, at outside entrance.

Fig. 14. CROSS-SECTIONS OF COAL SEAMS AT MELMONT AND MONTEZUMA.

In the advance mining up the dip, wood brattices nailed to the props are carried up one side of the room or chute to serve for ventilation and to partition off a traveling way, or canvas may be used in the same way. Steps are made by laying sills above the props and hitching these in the coal. The other part of the room is used as the runway or chute for the coal and is timbered as the circumstances require. Wingwalls are built of boards at every crosscut brattice to deflect air to the manways and to direct any coal which may drop down the manways into the chute. Batteries are built in the chutes to hold the coal at crosscut intervals and also to serve as reinforcing timbering at the crosscut openings. One chute may be used to bring the timber to the various crosscuts from the top gangway. The mined coal from the rooms is held behind the batteries to be drawn off as required or may be sent down to the gangway immediately.

As fast as the rooms are driven to the limit of the lift and a sufficient number of them are in advance, the pillars are drawn down to the counter below. The exact methods of drawing vary. In one method, one side of the pillar, inbye or outbye, depending on the position of the chute, is removed in a diagonal cut which removes the upper corner and permits the coal to run into the chute along the rib thus made. Each block of the pillar is thus successively removed and heavy cog timbering placed below the crosscuts to support the cover above the working place. In another method of drawing, both inbye and outbye sides of any pillar are attacked and permitted to run down the corresponding chutes. The timbering is carried along as before. It will be noted that the pillars are always drawn from the top gangway down to the counter.

Coal is shot from the solid in practically all of the mines, although, in some cases, a kerf is made in one of the soft bands in the seam known as the "mining." Holes are drilled by hand machines and dynamite is the blasting agent. Some mines employ shot-lighters, others permit the miner to fire the shots.

The dip is usually steep enough to permit the coal to travel

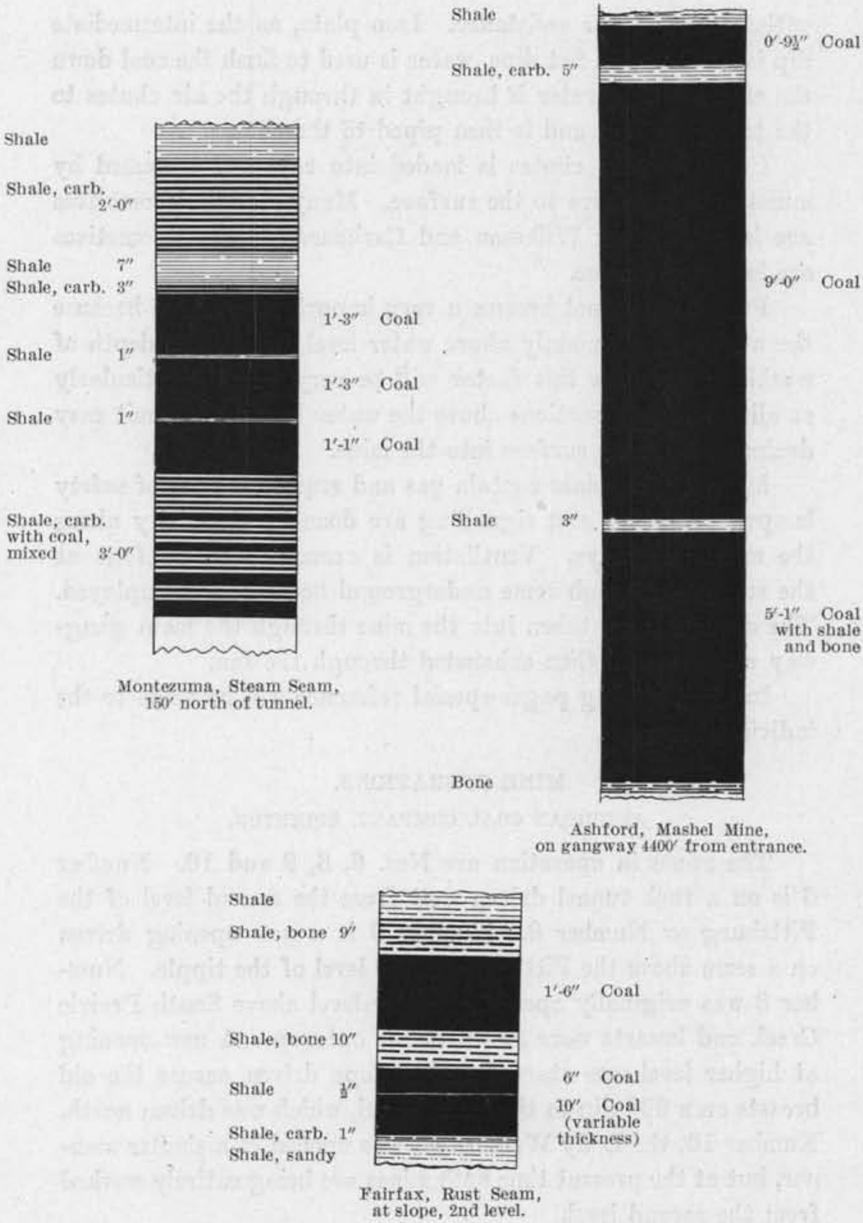


Fig. 15. CROSS-SECTIONS OF COAL SEAMS AT MONTEZUMA, FAIRFAX, AND ASHFORD.

without bucking or assistance. Iron plate, on the intermediate dip is used, and in flat dips, water is used to flush the coal down the chutes. The water is brought in through the air chutes to the top gangways and is then piped to the chutes.

Coal from the chutes is loaded into cars and trammed by mules or locomotives to the surface. Many electric locomotives are in use and at Wilkeson and Carbonado steam locomotives are in active service.

Pumping has not become a very important problem because the workings are mainly above water level, but as the depth of workings increases this factor will be very great, particularly as all the robbed portions above the water level will permit easy drainage from the surface into the mine.

Many of the mines contain gas and require the use of safety lamps. Lighting and signalling are done by electricity along the main gangways. Ventilation is accomplished by fans at the surface although some underground boosters are employed. The air is usually taken into the mine through the main gangway or slope and then exhausted through the fan.

In the following pages special reference will be made to the individual mines.

MINE OPERATIONS.

AMERICAN COAL COMPANY, SPIKETON.

The mines in operation are Nos. 6, 8, 9 and 10. Number 6 is on a rock tunnel driven west from the second level of the Pittsburg or Number 8. Number 9 is a new opening driven on a seam above the Pittsburg at the level of the tipple. Number 8 was originally opened at water level above South Prairie Creek and breasts were mined to the outcrop. A new opening at higher level was started and a slope driven across the old breasts on a 30° dip to the second level, which was driven north. Number 10, the Lady Wellington, was opened in a similar manner, but at the present time both mines are being entirely worked from the second level.

The system of mining employed is similar to that given under the general description. [Figure 16.] The main level is

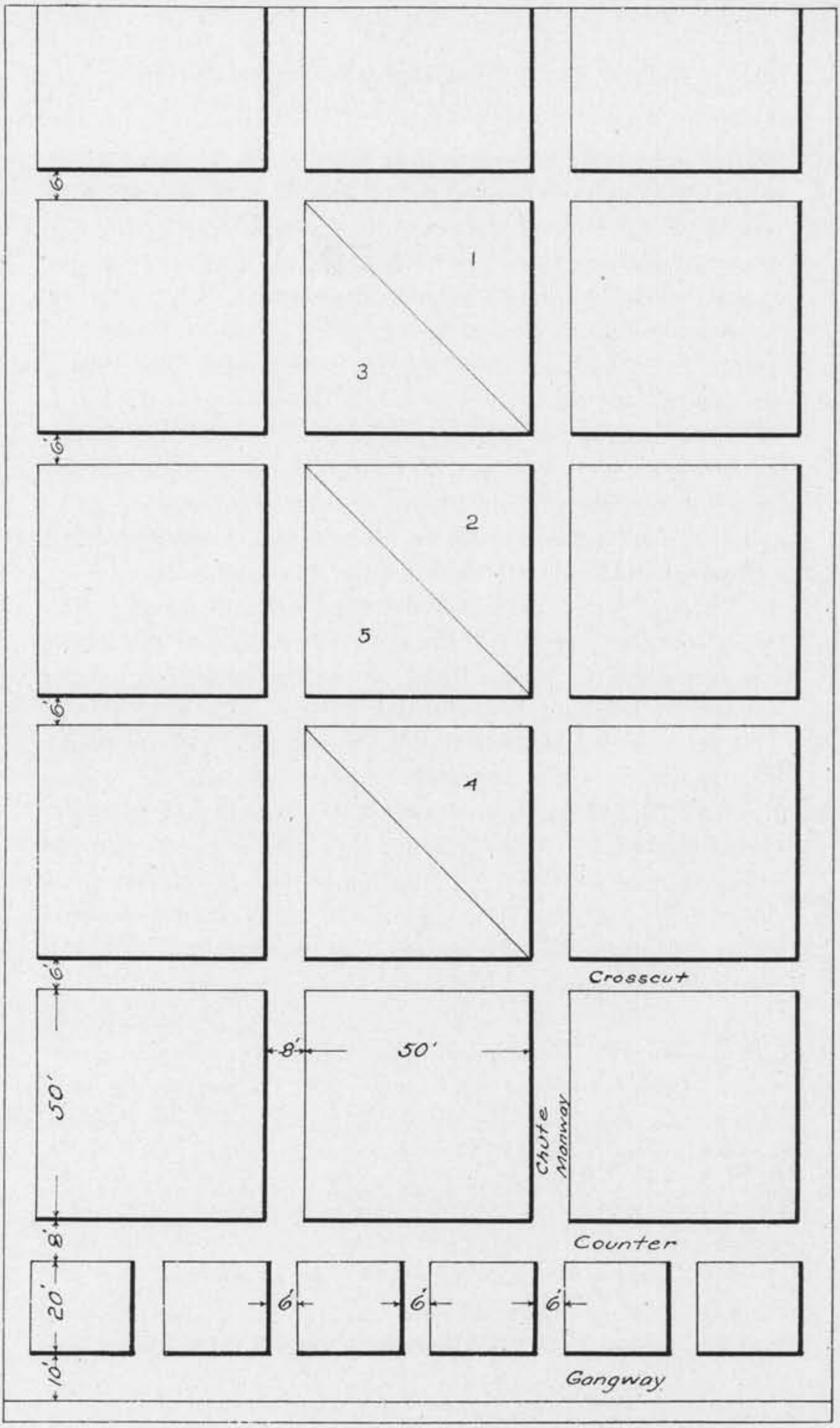


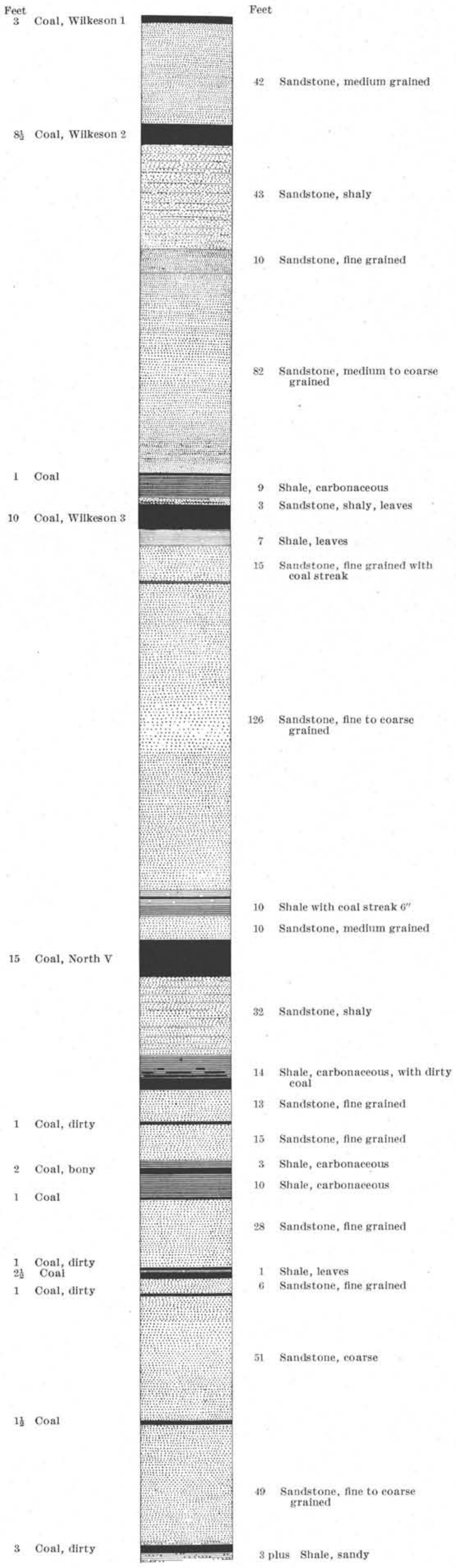
Fig. 16. System of Mining, American Coal Co., Spiketon.

10 feet wide and the counter 6 or 8 feet, with a 20-foot pillar between. Chutes are opened 6 feet wide but are widened to 8 feet above the counter. The width of pillar varies in the different seams from 35 feet to 50 feet, but up the dip the length is usually 50 feet with 6-foot crosscuts between. The gangway or stump pillar is pierced by a crosscut connected with the counter to be used as a traveling way to the chutes. The breasts are divided into the chute proper and the manway, each 4 feet wide, the manway on the inbye side. These chutes are driven to the top counter, leaving a 50-foot pillar below to provide for bringing in timber. Four chutes are driven in advance inside and then four blocks are drawn. The attack is always on the outbye side and cuts are taken in the order indicated on Figure 16 from the upper block down. Cogs are placed in the robbed portions and bulkheads and chute are taken out as the coal is run down. Monobel and 20 per cent stumping powder are used for bringing down the coal.

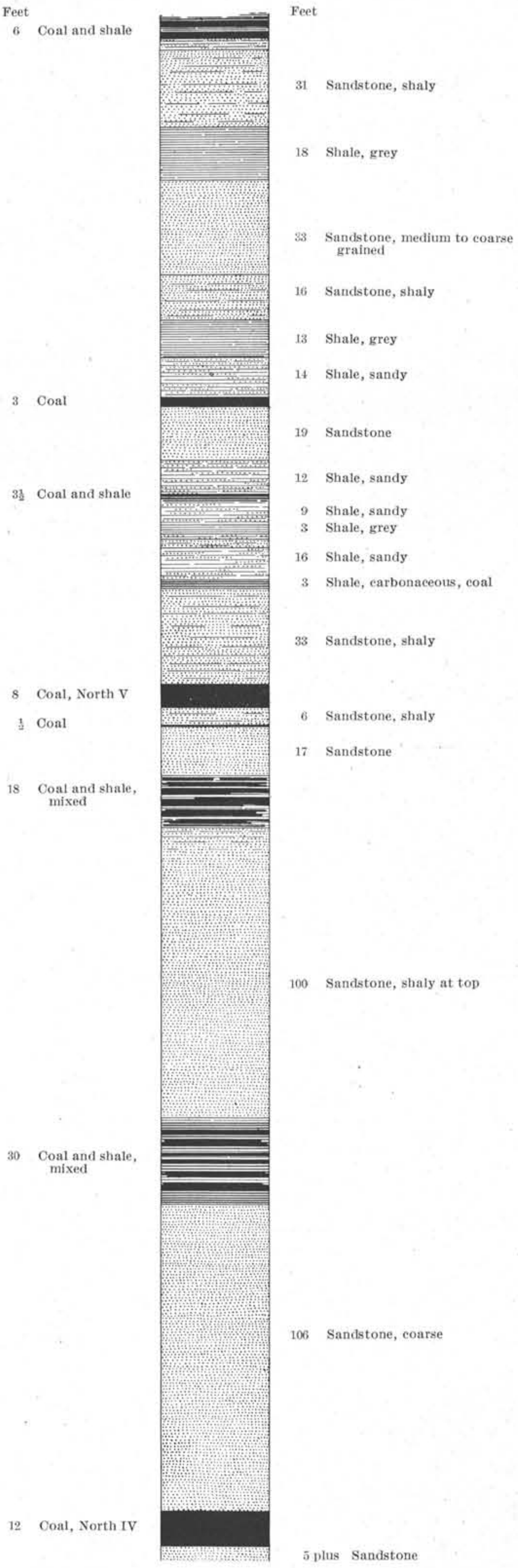
Rock tunnels from both the Wellington and Pittsburg seams have been driven for prospect purposes. Two small seams, Numbers 11 and 12, were struck in the tunnel east from the second level of the Wellington but they did not prove valuable enough for development. A long tunnel was driven west from the lower level of the Pittsburg and this cut a number of seams which served to assist in correlating the Spiketon with the South Willis sections. Two of these seams, Number 7 and Number 6 will be of commercial importance. Number 6 has already been developed, but Number 7 has not been of as great value. Coal from these seams will reach the surface by way of the rock tunnel and the Pittsburg slope, which now delivers its coal to a surface landing at the tipple level and is then taken by electric locomotive to the tipple which is at the head of the Wellington slope.

SOUTH WILLIS COAL COMPANY, SOUTH WILLIS.

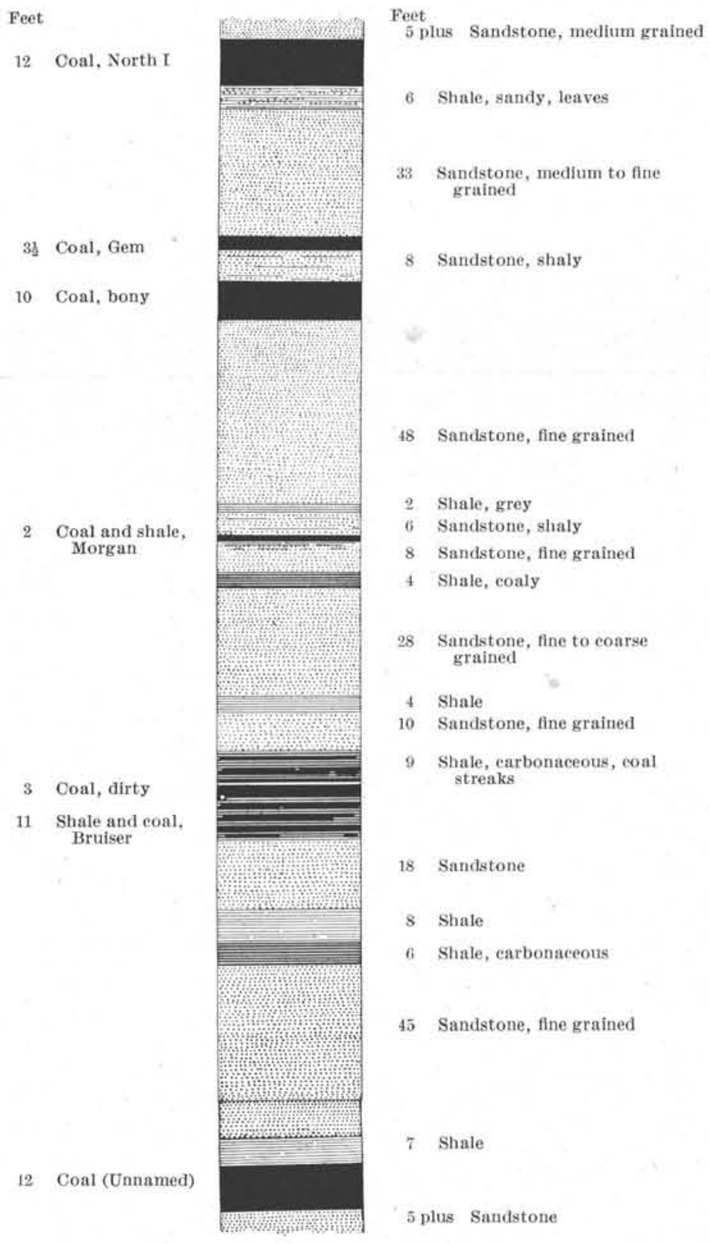
The same general method of mining that is employed at Spiketon is followed at South Willis. The Winsor, the Champion, and the Peacock have all been opened by drifts into the



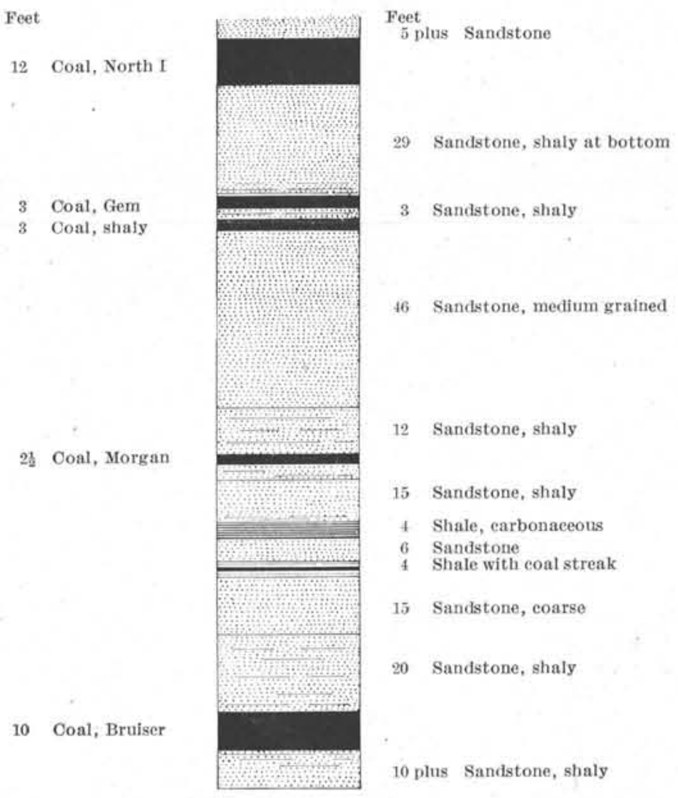
CARBONADO. SECTIONS "L" AND "M", AT WILKESON SEAMS, NORTH 1 MINE.



CARBONADO. SECTION "O", NORTH 1 MINE, NUMBER 33 TUNNEL.



CARBONADO. SECTION "N", NORTH 1 MINE ON TUNNEL TO WILKESON SEAMS.



CARBONADO. SECTION "P", NORTH 1 MINE ON TUNNEL FROM BRUISER TO NORTH 1 SEAM.

Columnar sections of Carbonado formation exposed in rock tunnels at Carbonado.

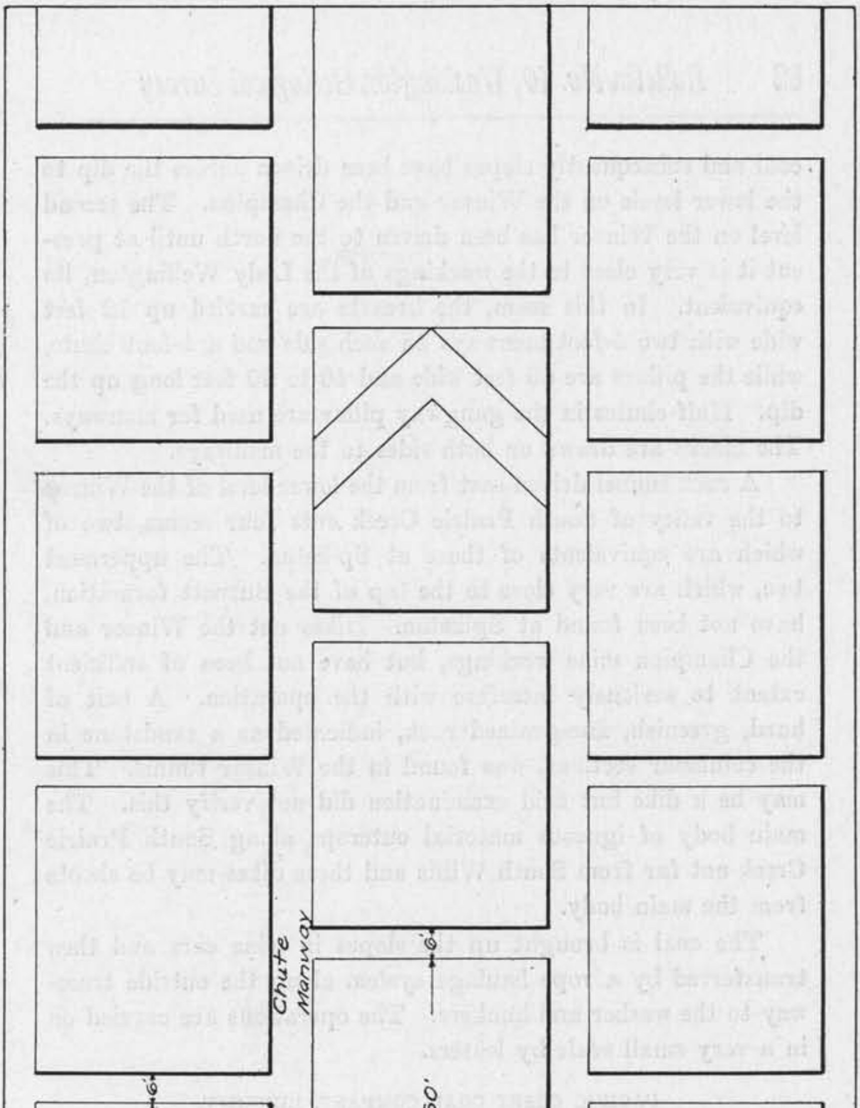


Fig. 17. System of Mining, Pacific Coast Coal Co., Burnett.

coal and subsequently slopes have been driven across the dip to the lower levels on the Winsor and the Champion. The second level on the Winsor has been driven to the north until at present it is very close to the workings of the Lady Wellington, its equivalent. In this seam, the breasts are carried up 12 feet wide with two 4-foot manways on each side and a 4-foot chute, while the pillars are 50 feet wide and 40 to 50 feet long up the dip. Half-chutes in the gangway pillar are used for manways. The blocks are drawn on both sides to the manways.

A rock tunnel driven east from the lower level of the Winsor to the valley of South Prairie Creek cuts four seams, two of which are equivalents of those at Spiketon. The uppermost two, which are very close to the top of the Burnett formation, have not been found at Spiketon. Dikes cut the Winsor and the Champion mine workings, but have not been of sufficient extent to seriously interfere with the operation. A belt of hard, greenish, fine-grained rock, indicated as a sandstone in the columnar sections, was found in the Winsor tunnel. This may be a dike but field examination did not verify this. The main body of igneous material outcrops along South Prairie Creek not far from South Willis and these dikes may be shoots from the main body.

The coal is brought up the slopes in mine cars and then transferred by a rope haulage system along the outside tramway to the washer and bunkers. The operations are carried on in a very small scale by leasers.

PACIFIC COAST COAL COMPANY, BURNETT.

The original opening at this mine was a water-level drift on the Number 1 seam, east dip, on the south side of South Prairie Creek [PLATE XXVI A], but this was soon followed by a slope in the coal developing two lower levels. These levels were extended to the south end of the property. A rock tunnel driven westward struck the Number 2 seam and the seams on the east dip were further developed from these rock tunnels. Subsequently, a rock slope from a higher elevation was sunk to strike the Number 2 seam on the east dip. The slope was

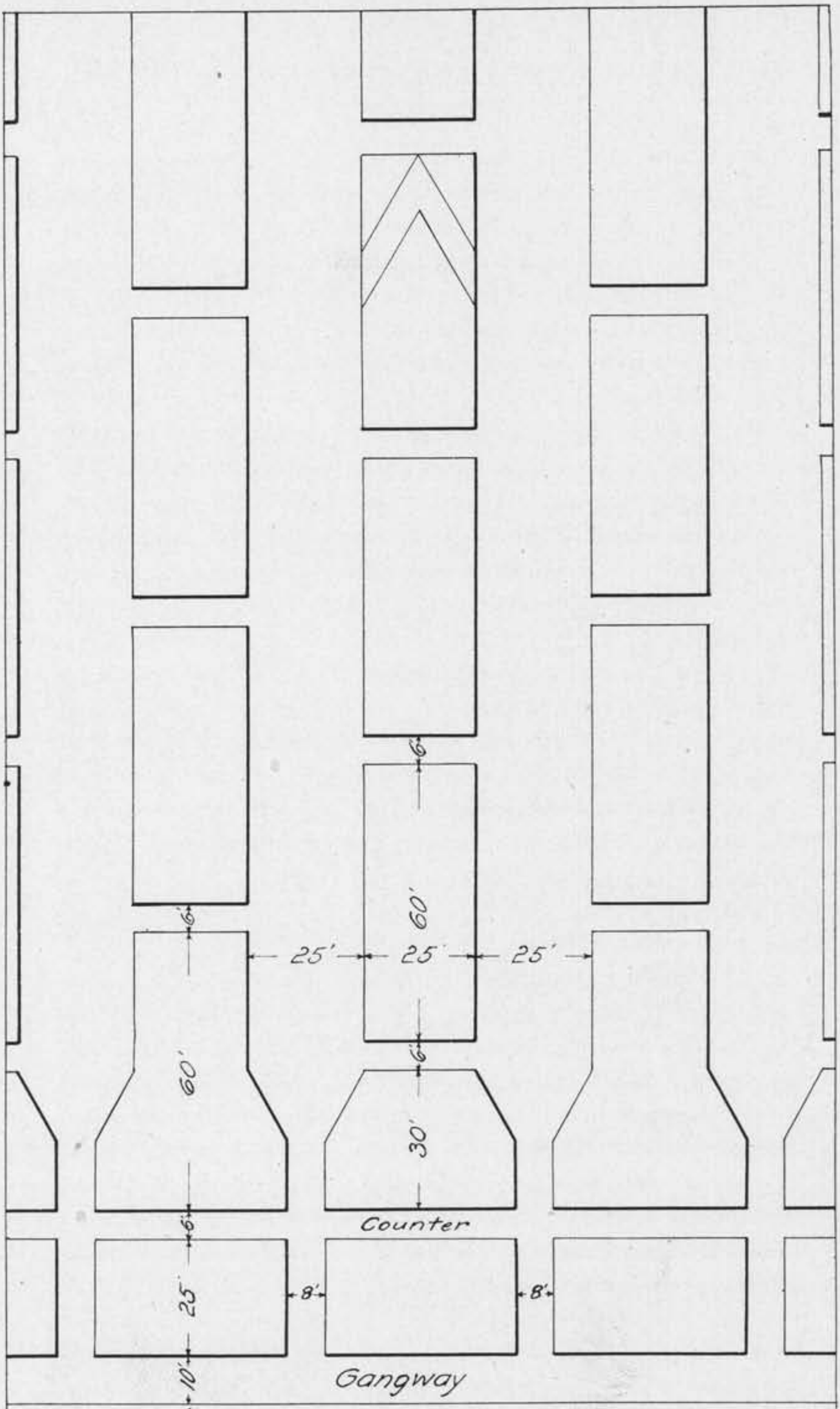


FIG. 18. System of Mining, Pacific Coast Coal Co., Burnett.

then continued in the coal across the dip to the second level. This slope is now the main hoisting way for all the coal mined at Burnett, and is being extended to the third level. Rock tunnels on the elevation of the second level cut all the seams being worked on both dips and serve as arteries to the main slope.

Two types of rooms are mined here. In one, figure 17, the chutes are carried up the pitch 8 feet wide on 50-foot centers with a 25-foot pillar to the counter, and crosscuts staggered every 60 feet. The manway is 4 feet wide all the way up from the gangway. Four breasts are mined, leaving a 200-foot solid block to the next set. When the four breasts are mined, three pillars are drawn, all three at the same time and each pillar is drawn toward the chute on each side. Cogs are put in each crosscut as the room is driven up. On a heavy dip batteries are used.

In the other type of rooms, figure 18, the neck is carried up 8 feet wide to a point above the counter gangway where it is widened to 25 feet, the full width of the breast. The pillar at this point is 25 feet thick. A manway 4 feet wide is carried up on each side of the breast and on one side of the chute at the gangway. The pillar is drawn toward each manway. Forty per cent powder is used and all firing is done by shot lighters.

GALE CREEK COAL MINES COMPANY, WILKESON.

This property is opened by a rock tunnel into the hillside to tap the Number 2 seam on which a slope is carried on full dip to the second gangway. A rock tunnel west from this gangway cuts the Queen gangway from which most of the coal is at present shipped. The slope on the Number 2 seam is being extended to a lower level.

Breasts are carried up on full dip with widths up to 21 feet and pillars 40 feet thick. Each breast is drawn as soon as finished. Some dips are very flat and coal is bucked by using canvas on galvanized iron plate.

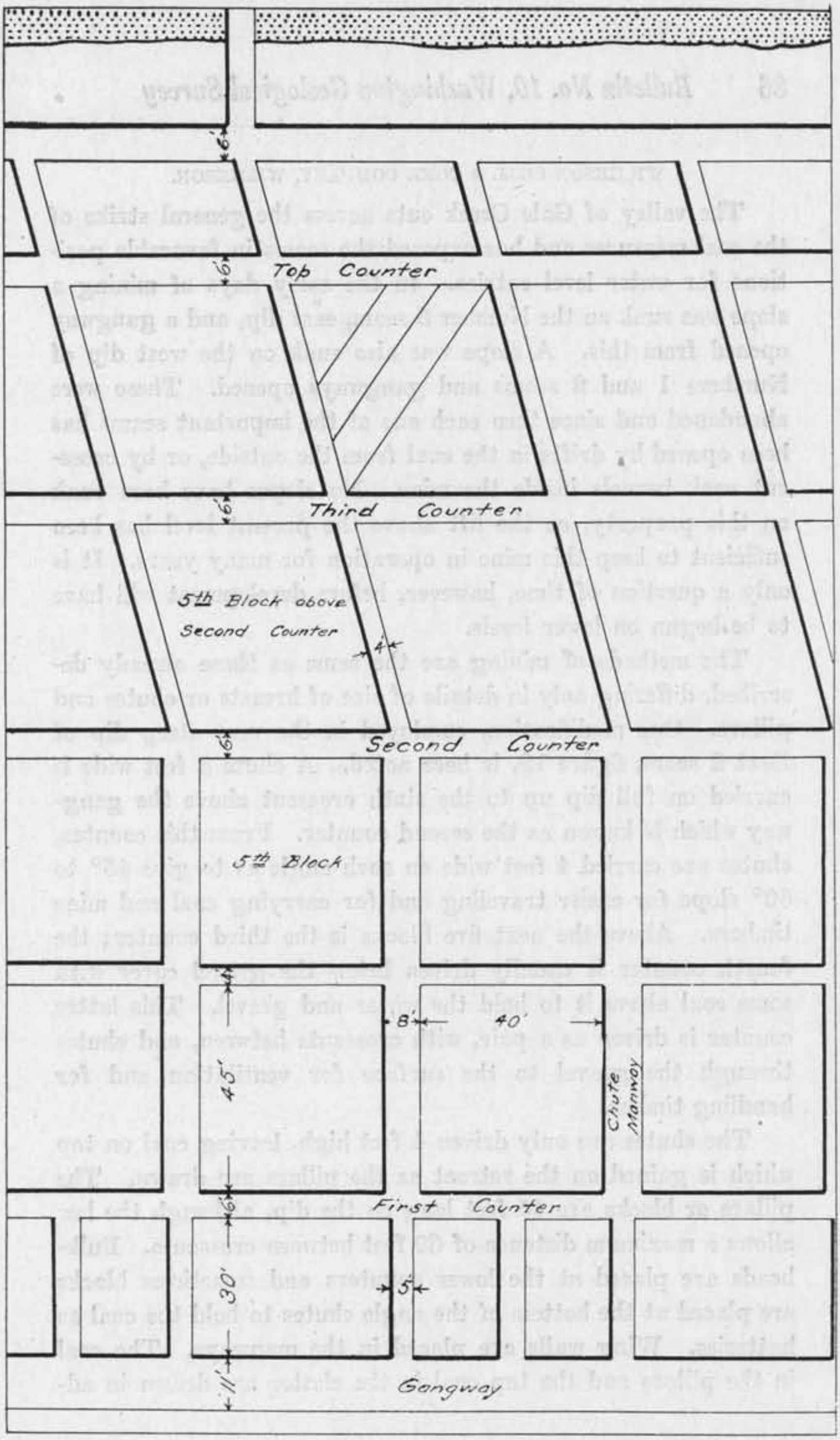


FIG. 19. System of Mining, East 2 Seam, Wilkeson Coal & Coke Co.

WILKESON COAL & COKE COMPANY, WILKESON.

The valley of Gale Creek cuts across the general strike of the coal measures and has exposed the seams in favorable positions for water level entries. In the early days of mining a slope was sunk on the Number 3 seam, east dip, and a gangway opened from this. A slope was also sunk on the west dip of Numbers 1 and 2 seams and gangways opened. These were abandoned and since then each one of the important seams has been opened by drifts in the coal from the outside, or by crosscut rock tunnels inside the mine. No slopes have been sunk on this property, as the lift above the present level has been sufficient to keep this mine in operation for many years. It is only a question of time, however, before development will have to be begun on lower levels.

The methods of mining are the same as those already described, differing only in details of size of breasts or chutes and pillars. One modification, employed in the very steep dip of East 2 seam, figure 19, is here noted. A chute 8 feet wide is carried on full dip up to the sixth crosscut above the gangway which is known as the second counter. From this counter, chutes are carried 4 feet wide on such angle as to give 45° to 50° slope for easier traveling and for carrying coal and mine timbers. Above the next five blocks is the third counter; the fourth counter is usually driven below the gravel cover with some coal above it to hold the water and gravel. This latter counter is driven as a pair, with crosscuts between, and chutes through the gravel to the surface for ventilation and for handling timber.

The chutes are only driven 4 feet high, leaving coal on top which is gained on the retreat as the pillars are drawn. The pillars or blocks are 45 feet long on the dip, although the law allows a maximum distance of 60 feet between crosscuts. Bulkheads are placed at the lower counters and sometimes blocks are placed at the bottom of the angle chutes to hold the coal as batteries. Wing walls are placed in the manways. The coal in the pillars and the top coal in the chutes are drawn in ad-

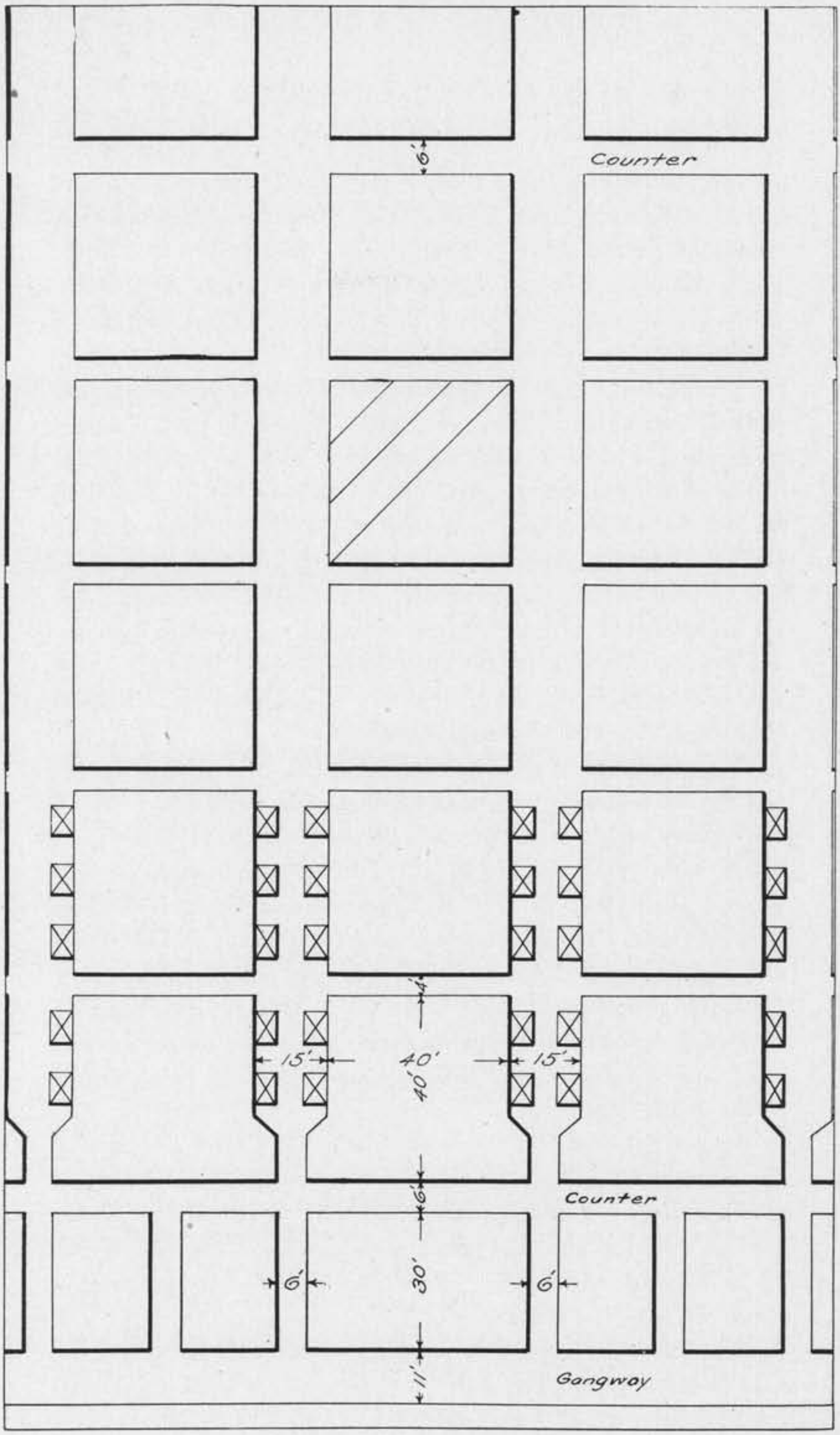


FIG. 20. System of Mining, East 3 Seam, Wilkeson Coal & Coke Co.

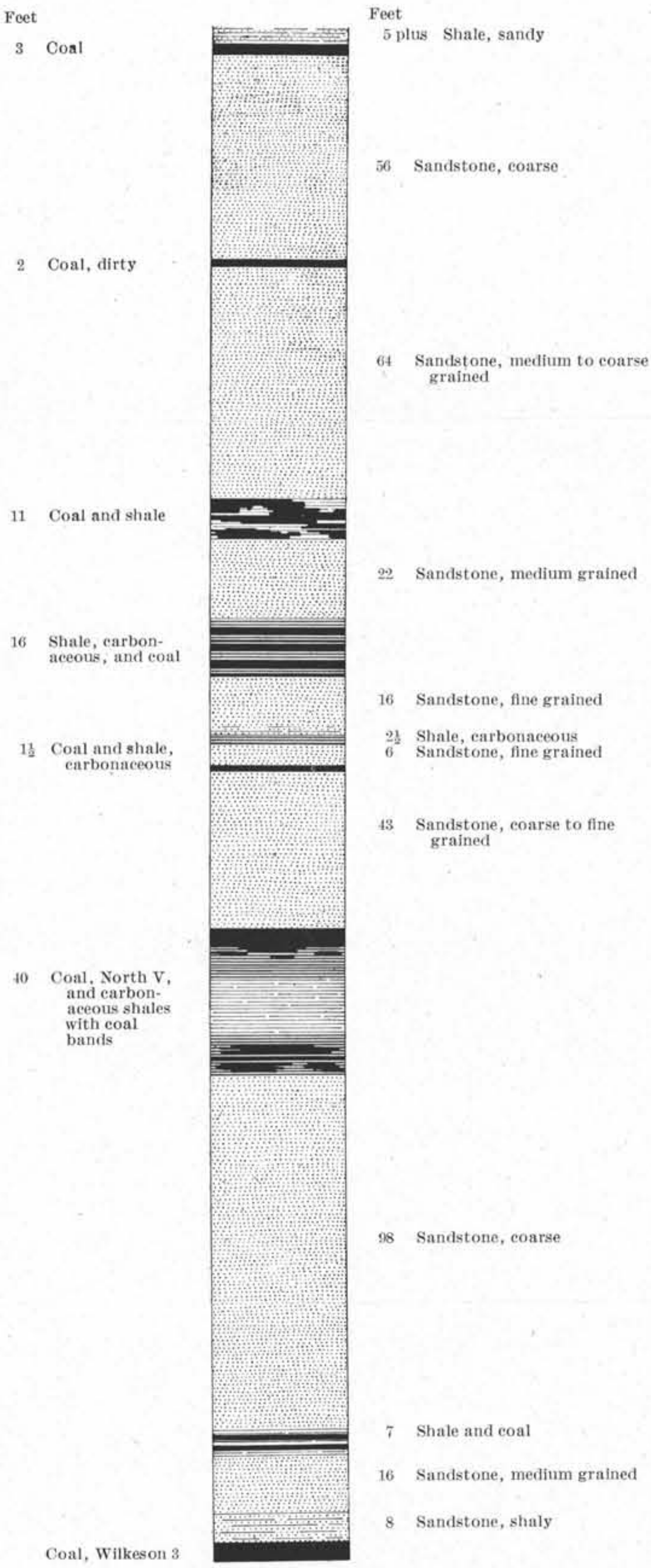
vancing order of pillars, that is, the outside pillars are drawn first. The pillar, however, is attacked from the inside and run down the outside chute, the manways being inbye. On the angle chutes, a thin pillar 3 to 4 feet wide is left on the outside all the way up the block as a cushion. Cogs are placed in robbed areas.

In the ventilation of these workings, air from the surface chute is taken along the upper counter where it is split, one part going to the narrow work or chutes, the other to the pillar work. Each crosscut is curtained off to keep the air traveling toward the working faces. In the chutes the air travels along the face crosscuts down to the counter, thence to face of chute and out by way of the gangway. In the pillar workings, the air is conducted so that a block of coal is above it, but allowing some air to leak to the open ground below it to the lower pillars from which it travels by way of the counter to a half-chute and then out the main gangway.

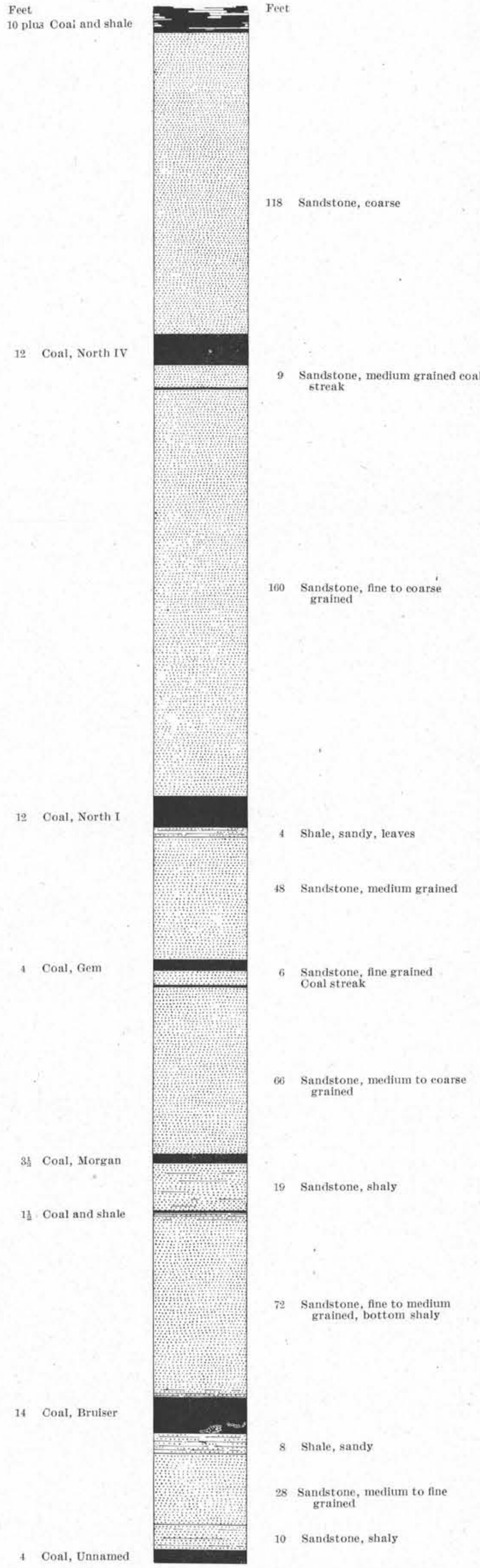
In the East 3 seam, figure 20, breasts are carried up the full dip 15 feet wide with necks 6 feet wide, and pillars are 40 feet square with 4 foot crosscuts between blocks. Counters are 6 feet wide every five blocks. The breasts are cogged 6 feet apart against the ribs and the open space between is used as the coal chute. The counters are used for airways and traveling ways, and every fifth breast is left open for traveling, the entry from the gangway is by a half-chute. Pillars are drawn as already described toward the outbye side as fast as the breasts reach the upper limit, and three or four pillars are being drawn at the same time.

In the Southeast 2 gangway, figure 21, chutes are carried up 5 feet wide on the full dip with 40 foot blocks. Canvas is used to carry air and no wing walls are used. Batteries are used at the counters, but the coal is drawn as fast as mined. The chutes are carried four or five feet high and the top coal is taken out with the pillars.

The West 2 gangway is the main entry to all the seams except Number 4 and Number 5 which have separate entrances.



CARBONADO. SECTION "M" ON ROCK TUNNEL FROM NORTH 1 TO WILKESON 3 SEAM.



CARBONADO. SECTION "Q", NORTH 1 ROCK TUNNEL.

Columnar sections Carbonado formation exposed in rock tunnels at Carbonado.

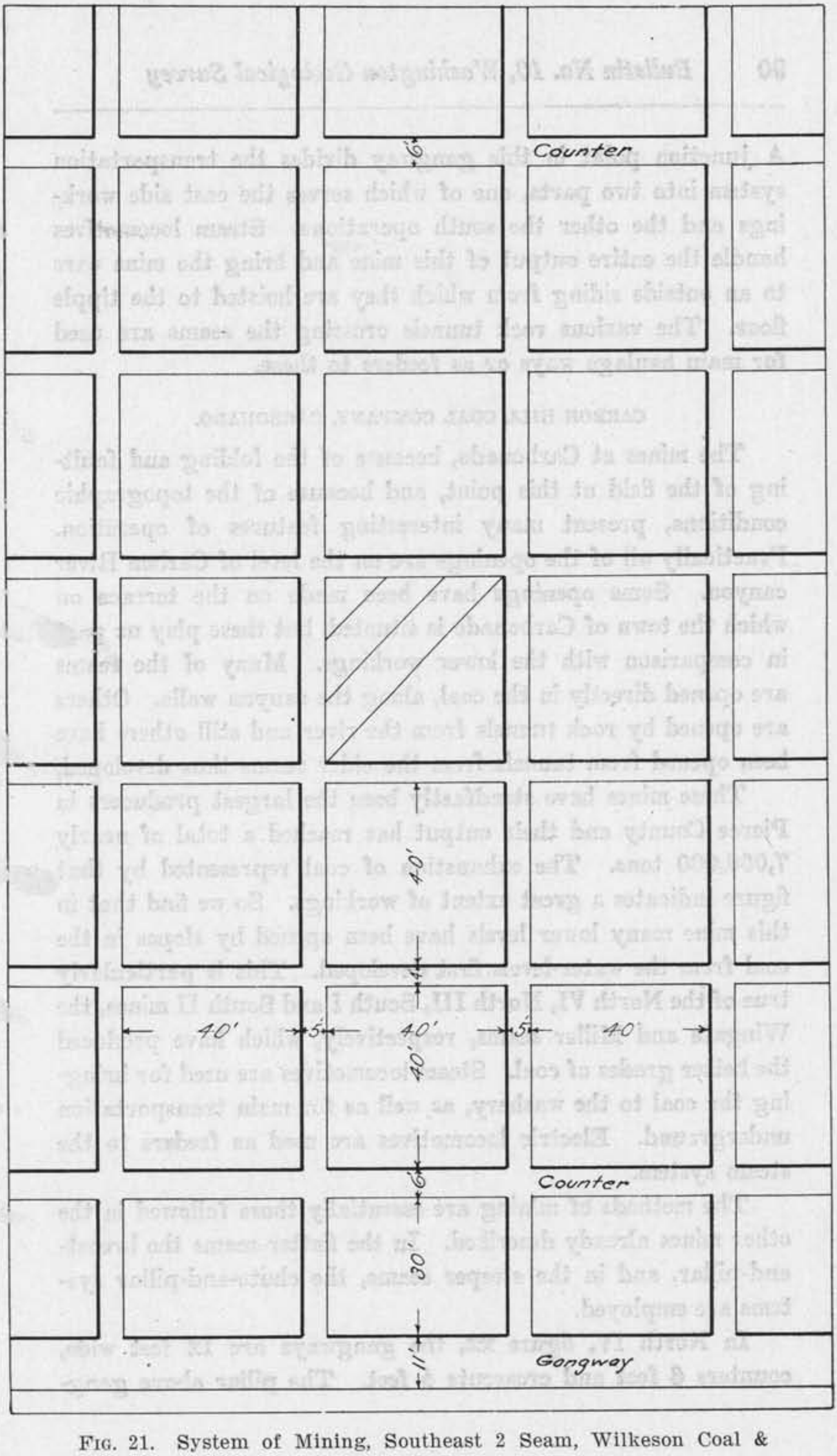


FIG. 21. System of Mining, Southeast 2 Seam, Wilkeson Coal & Coke Co.

A junction point in this gangway divides the transportation system into two parts, one of which serves the east side workings and the other the south operations. Steam locomotives handle the entire output of this mine and bring the mine cars to an outside siding from which they are hoisted to the tipple floor. The various rock tunnels crossing the seams are used for main haulage ways or as feeders to these.

CARBON HILL COAL COMPANY, CARBONADO.

The mines at Carbonado, because of the folding and faulting of the field at this point, and because of the topographic conditions, present many interesting features of operation. Practically all of the openings are on the level of Carbon River canyon. Some openings have been made on the terrace on which the town of Carbonado is situated, but these play no part in comparison with the lower workings. Many of the seams are opened directly in the coal, along the canyon walls. Others are opened by rock tunnels from the river and still others have been opened from tunnels from the older seams thus developed.

These mines have steadfastly been the largest producers in Pierce County and their output has reached a total of nearly 7,000,000 tons. The exhaustion of coal represented by that figure indicates a great extent of workings. So we find that in this mine many lower levels have been opened by slopes in the coal from the water-levels first developed. This is particularly true of the North VI, North III, South I and South II mines, the Wingate and Miller seams, respectively, which have produced the better grades of coal. Steam locomotives are used for bringing the coal to the washery, as well as for main transportation underground. Electric locomotives are used as feeders to the steam system.

The methods of mining are essentially those followed in the other mines already described. In the flatter seams the breast-and-pillar, and in the steeper seams, the chute-and-pillar systems are employed.

In North IV, figure 22, the gangways are 12 feet wide, counters 6 feet and crosscuts 4 feet. The pillar above gang-

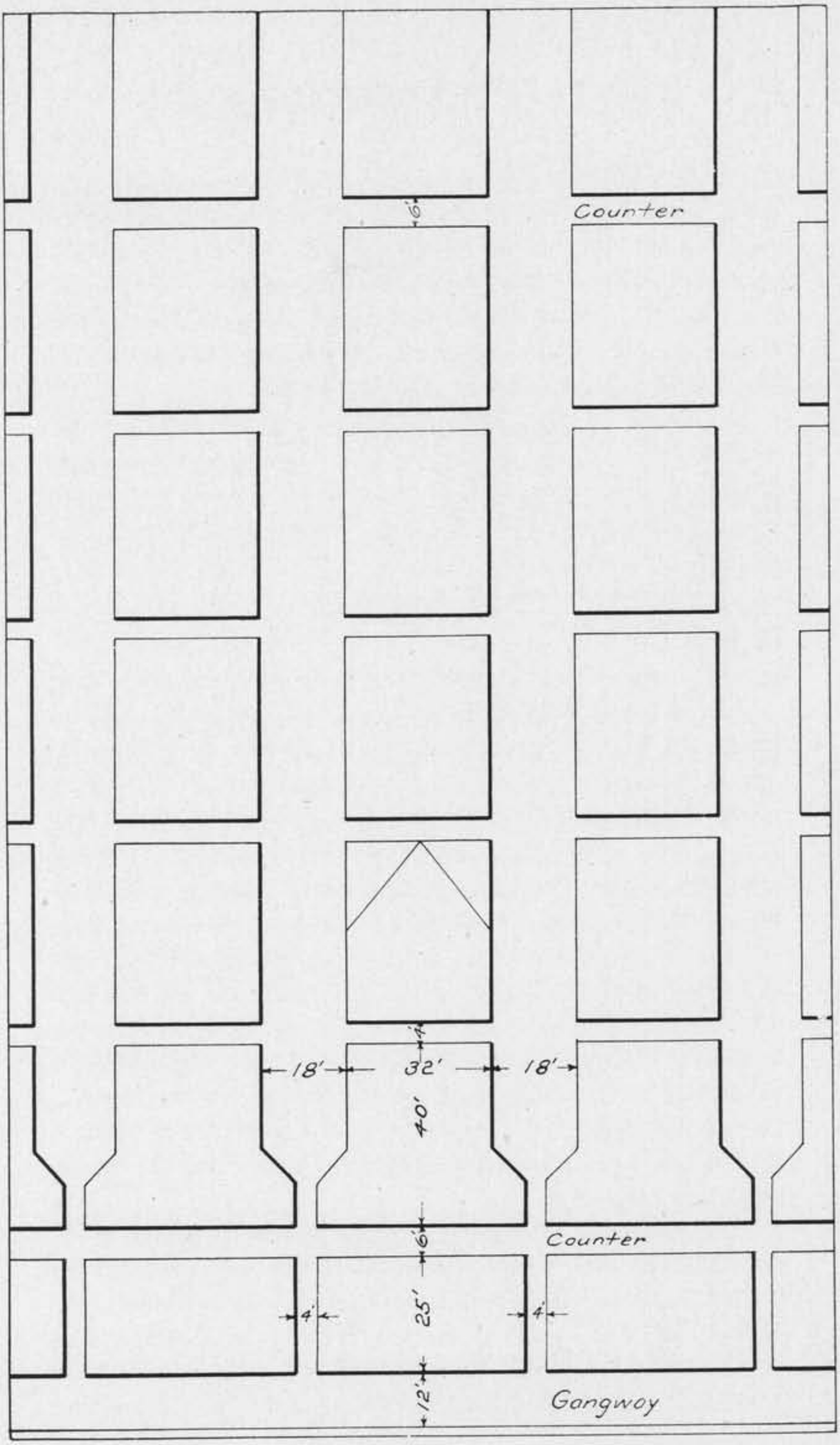


FIG. 22. System of Mining, North IV Mine, Carbon Hill Coal Company.

way is 25 feet thick and the blocks are 40 feet long up the dip. Room necks are 4 feet wide and breasts average 18 feet on 50 foot centers. The manway is on the outbye side and canvas is used for brattices. Sheet iron chutes are used to run the coal. The breast is carried on the full height of the coal and sometimes cogs are set on the way up. In drawing pillars, the coal is taken off on both sides to adjacent breasts.

In North VI, figure 23, the chutes are carried up 4 feet wide, all the way up the dip, in the bottom coal 4 feet high. The blocks are 50 feet square. Sometimes the chutes are angled to get an easier grade for the coal. Pillars are drawn on two sides to adjacent chutes.

A modified system of longwall has been attempted in South IX.

NORTHWESTERN IMPROVEMENT COMPANY, MELMONT.

The igneous dike which limits the south side workings at Carbonado marks the valley walls of the Carbon River to a point near Melmont. Here a rock tunnel driven east cuts a number of seams on a series of anticlines and synclines. The anticlinal seams have been worked up to their saddles from gangways driven north. Number 3 seam is the only one worked at a lower level. A slope from the surface has been carried down on the full dip of the coal and a second lift worked from this northward until the "nose" of the anticlinal axis was reached. The slope is being extended to open ground for a new lift, but in sinking a faulted basin was encountered. All of the present production of this mine is from the Number 3 seam and is handled by skips in the slope. A pocket in the slope receives the coal from the mine cars which are hauled from the chutes by electric locomotives.

The system of working is slightly different from that employed in the other mines. Here the battery and block system is used. In this method a series of breasts, nine in number, are worked, and an equivalent block of coal is left between batteries. The blocks are subsequently mined in the same manner as the battery. Breasts are 18 feet wide on 60-foot centers, and

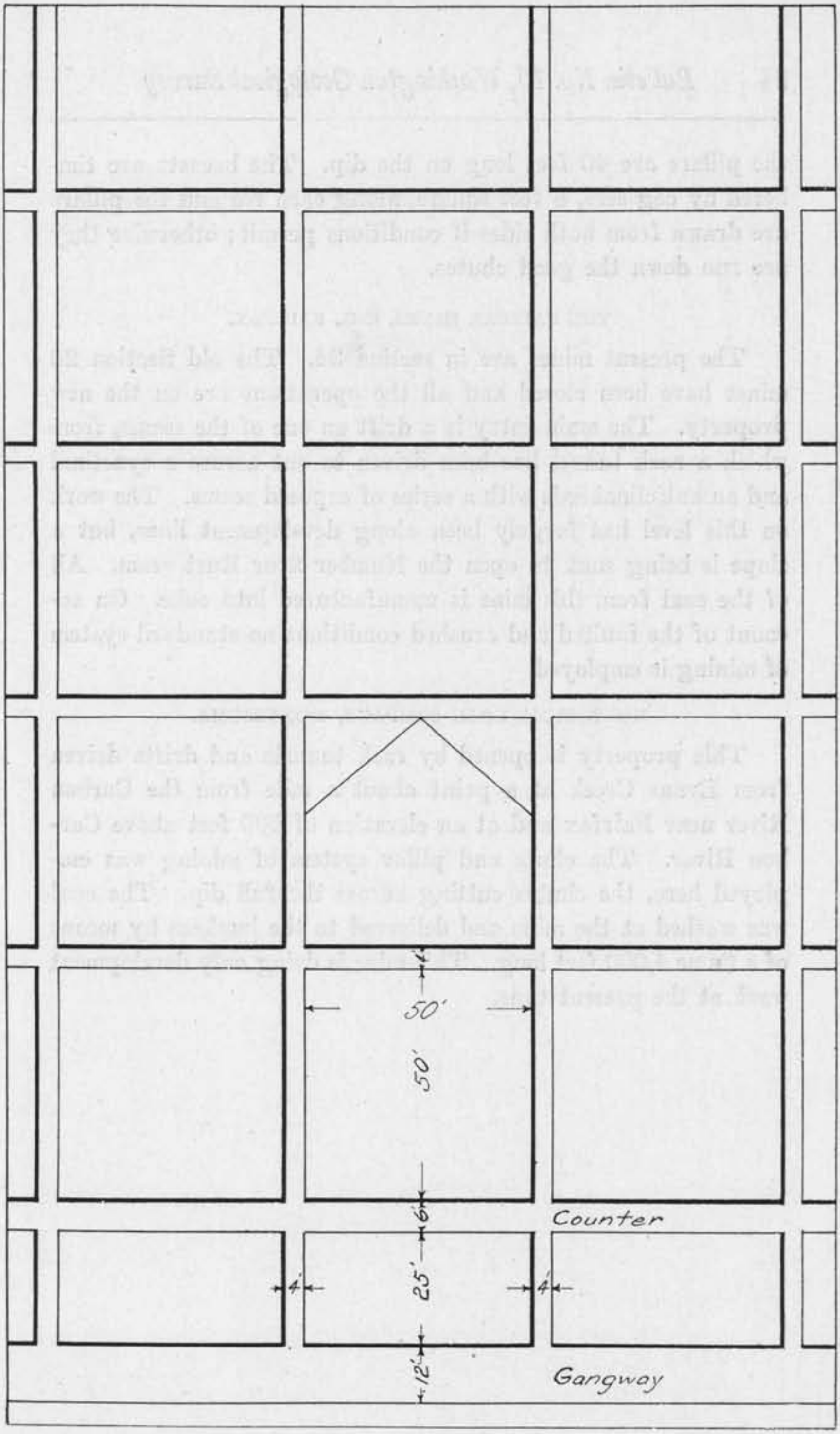


Fig. 23. System of Mining, North VI Mine, Carbon Hill Coal Company.

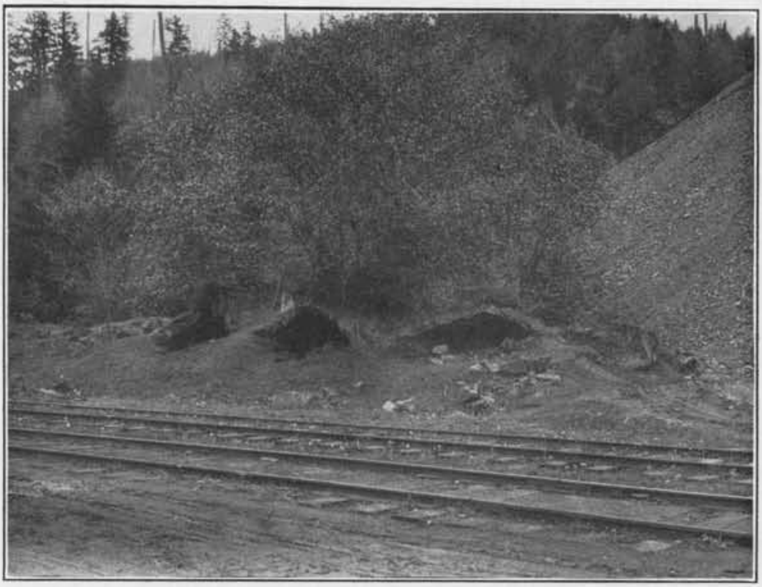
the pillars are 40 feet long on the dip. The breasts are timbered by cog sets, 6 feet square, along each rib and the pillars are drawn from both sides if conditions permit; otherwise they are run down the good chutes.

THE FAIRFAX MINES, INC., FAIRFAX.

The present mines are in section 34. The old Section 26 mines have been closed and all the operations are on the new property. The main entry is a drift on one of the seams, from which a rock tunnel has been driven to cut across a synclinal and an anticlinal axis with a series of exposed seams. The work on this level has largely been along development lines, but a slope is being sunk to open the Number 2 or Rust seam. All of the coal from this mine is manufactured into coke. On account of the faulted and crushed conditions no standard system of mining is employed.

MONTEZUMA COAL COMPANY, MONTEZUMA.

This property is opened by rock tunnels and drifts driven from Evans Creek at a point about a mile from the Carbon River near Fairfax and at an elevation of 500 feet above Carbon River. The chute and pillar system of mining was employed here, the chutes cutting across the full dip. The coal was washed at the mine and delivered to the bunkers by means of a flume 4,000 feet long. This mine is doing only development work at the present time.



A. Site of Early Coke Ovens, Wilkeson.

B. Coke Ovens and Tipple, Wilkeson Coal & Coke Company.

CHAPTER VI.

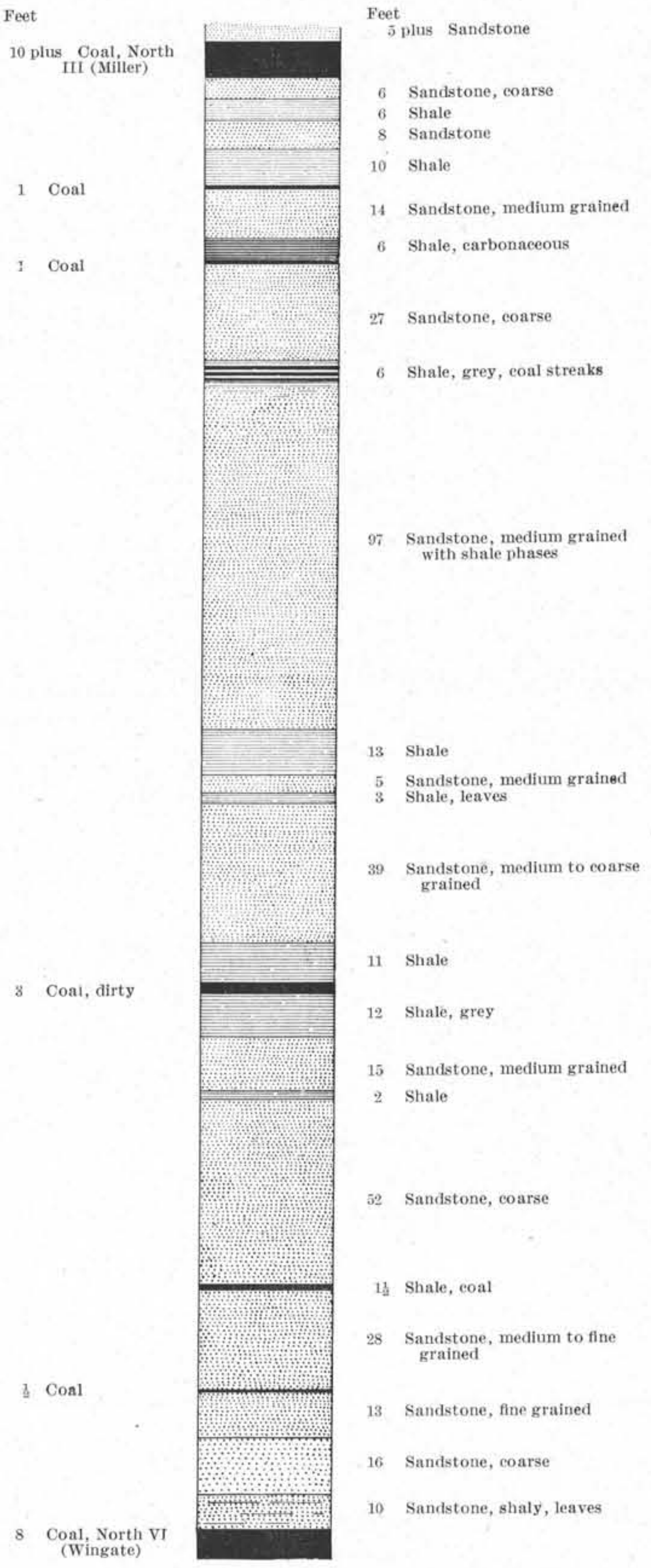
COAL PREPARATION.

CONTROLLING FACTORS.

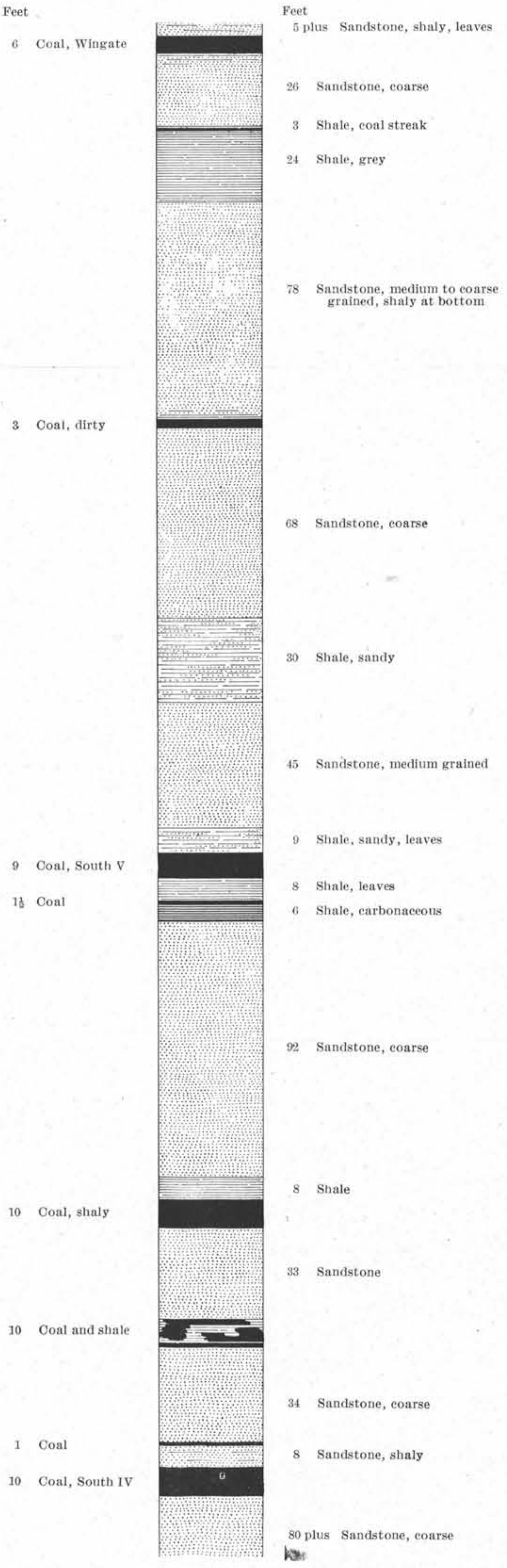
Examination of the table of analyses of coals from Pierce County shows a uniformly high percentage of ash. The lowest percentage on air-dried coal is 6.13, the highest is 34.01. The average on 48 analyses, including the above figures, is 15.76 per cent. If we omit the 34.01 per cent result, the next lowest high-ash is 24.10 per cent and the average for 47 analyses is 15.37 per cent. These figures are all for mine samples taken under uniform conditions everywhere, and "all material in the bed was included except partings, lenses, and binders more than three-eighths of an inch thick and lenses or concretions of 'sulphur' or other impurities greater than 2 inches in maximum diameter and half an inch in thickness."* Under these conditions the samples so taken are probably better samples than average mine run, and they are probably much better than the average washed coal. Sulphur runs less than 1 per cent and is not an important factor.

Those who are familiar with the methods of mining the pitching seams of Pierce County know that everything in the chutes and breasts goes to the washer, including all of the bands rejected in the above mentioned method of sampling, together with cap and bottom rock which cannot be handled except by sending it with the mine-run. In many cases all of this material goes directly to the washers without preliminary hand picking. The greater part of the non-carbonaceous material is removed by washing, but a large part of the original ash content of the seam proper cannot be removed because the ash is present as fine bands separating the coal and because the coal itself is high in original ash and in secondary ash due to the accumulation of fine silt that was intimately mixed with the vegetal

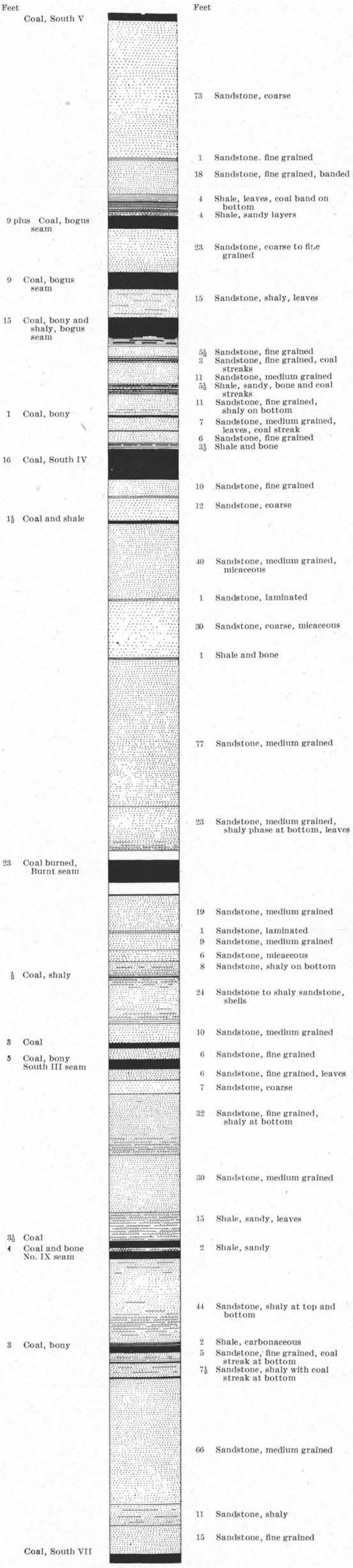
*U. S. Geol. Survey, Bulletin 474, Coals of the State of Washington, E. Eggleston Smith.



CARBONADO. SECTION "R", WATER LEVEL, NORTH VI MINE.

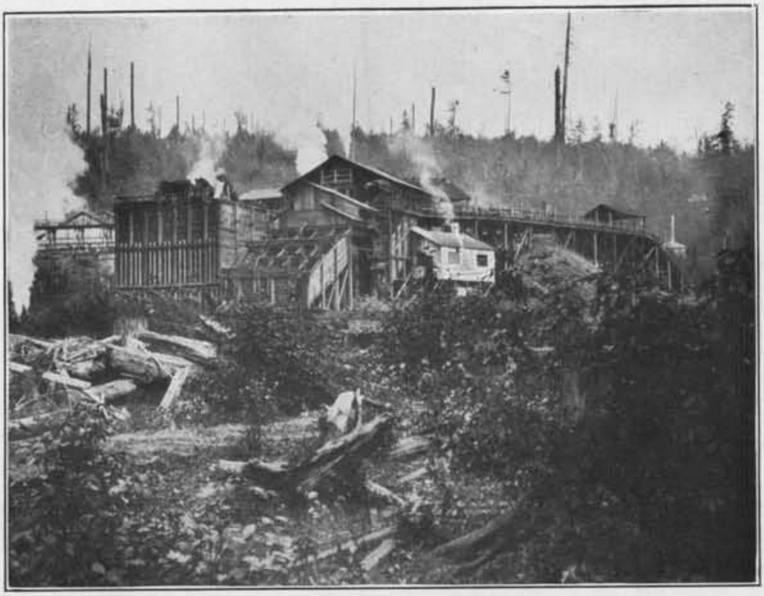


CARBONADO. SURFACE SECTION ALONG CARBON RIVER.

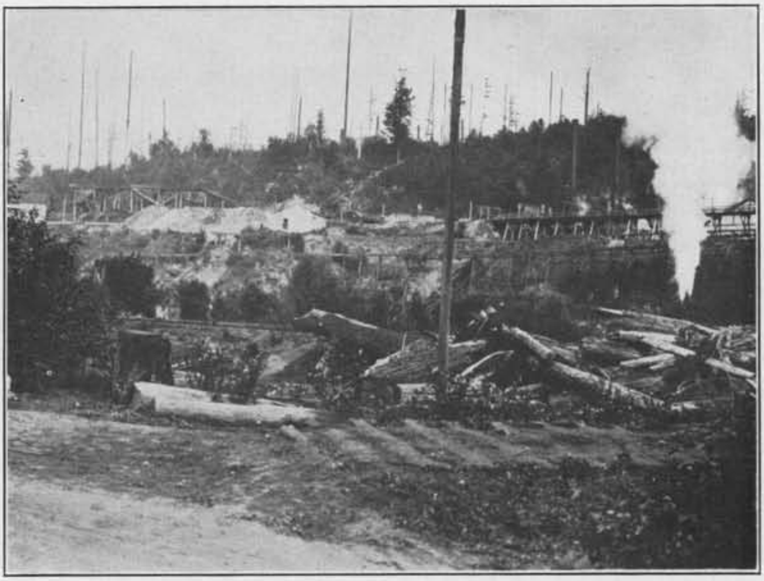


CARBONADO. SECTIONS "S" AND "T", SOUTH SIDE MINES.

Columnar sections of Carbonado formation exposed in rock tunnels and surface at Carbonado.



A. Lady Wellington Tipple and Bunker. Spiketon.



B. Pittsburg Slope. Spiketon.

matter at the time of deposition of the coal beds. The coal washing process is essentially the removal of the thicker bands in the coal seams and the elimination of the foreign material obtained in mining. The problem of reduction of ash in the coal itself is a second phase of the entire question.

The refuse in eastern coals will run as low as 6 per cent; in Washington the figures are from 15 to 20 per cent, with many single operations showing refuse in even greater quantities. The problem of removing the heavier shale and sandstone from the coal is simpler than the problem of getting a low ash product from the coal and bony coal. Separation at 1.7 specific gravity will eliminate all rock but will leave the bone and bony coal which is high in ash. In order to get ash low enough to pass commercial requirements the coals must generally be separated at 1.5 specific gravity. These figures are general and only float-and-sink tests on the various sizes from the individual seams will determine the proper washing point. The separation problem is further complicated by the practice of mixing coal from seams having widely differing washing properties.

Tests indicate that the finer sizes of Pierce County coal show a lower percentage of ash than the coarser sizes. This is highly important from the standpoint of a coking coal but it does not solve the problem of domestic and steam coals which must be of larger size and which therefore have correspondingly greater natural ash content.

OUTLINES OF WASHING PLANTS.

Practice in washing coal varies widely in details. In general, the mine-run is screened and the larger sizes handpicked and shipped as lump. The finer sizes are sent to tub washers, or to jigs, or these may be combined so that the tub product goes to jigs. Outlines of some of the washing plants are given, pages 103 to 112, and the exact procedure in each case can be worked out. It will be noted that all of the Pierce County coal is washed with the exception of the output from the Melmont mine whose washery was burned and not rebuilt.

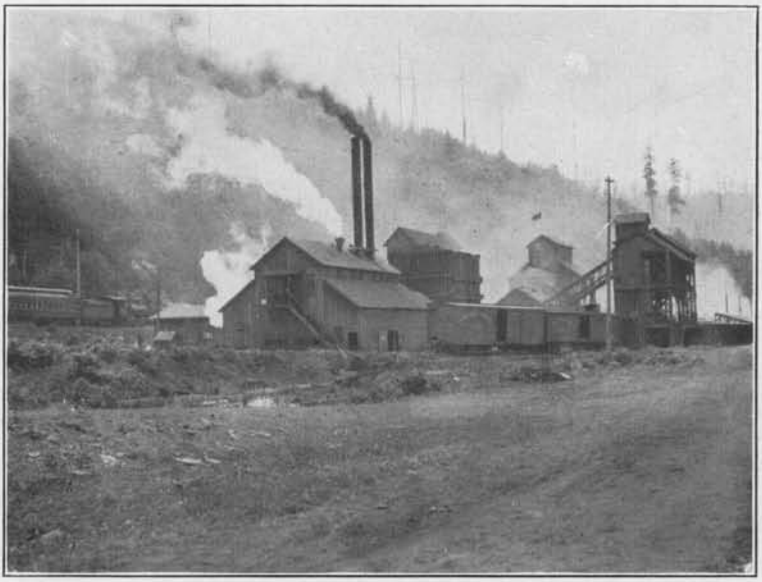
A. Carbonado. Incline to Carbon River.

B. Carbonado. Yard at Foot of Incline.

Because of the conditions peculiar to Washington coals, the problems of washing are local and individual and the methods in use in other parts of the country will not apply unless modified to meet these local conditions. Not enough study has been given to the problem, nor has sufficient experimental work been done to determine the best methods of washing. Such investigations are costly and coal operators do not feel justified in making the expenditure. Just so long as they can keep their markets satisfied they are content, but future competition will undoubtedly force better preparation of merchantable coal, and operators will recognize the value of a "pure coal" standard which will be uniform at all times and command as much confidence as the stamp "sterling" on silver. Otherwise they must be prepared to meet even greater competition from coals mined outside the state and from the use of oil.

The writer believes that there is ample opportunity to improve the grades of domestic and steam coals in spite of the inherent difficulty in washing these sizes. Undoubtedly the commercial sizes can be more efficiently washed and cleaned to remove the adhering bands of bone and shale which now remain in the coarser pieces, but this will be done at the expense of screening and crushing and will result in producing more coal of finer sizes. This will be desirable from the standpoint of coking, but from the domestic and steam standpoint it introduces difficulties. These, however, can be overcome. The finer sizes of coal are more and more being used under boilers and the price of high-grade coal in these sizes will undoubtedly rise. At the present time a large percentage of fines are made in the mining, in transportation down the chutes, and in the various operations of preparation. This percentage will be increased by the further crushing, screening and rewashing suggested as a means of getting a product lower in ash and higher in British thermal units, but the fine coal will be better suited to coking. The use of concentrating tables is suggested as a means of recovering very fine coal or sludge of low ash content. Briquetting may be

A. Melmont Mine. Melmont.

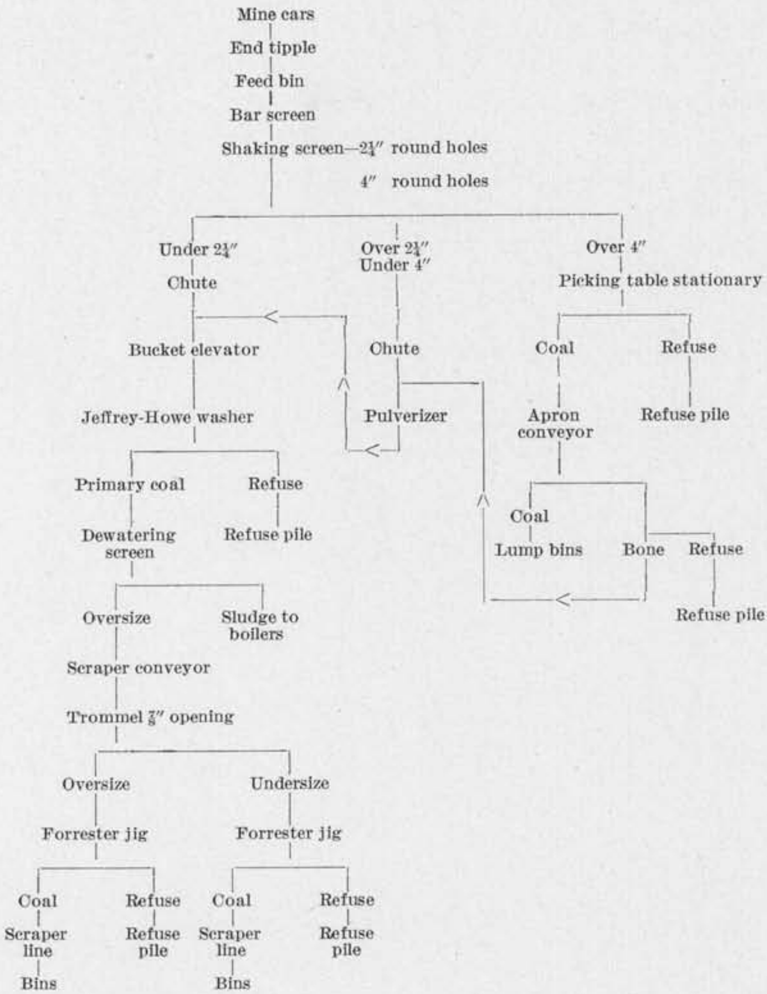


B. Surface Plant, Fairfax Mine, Fairfax.

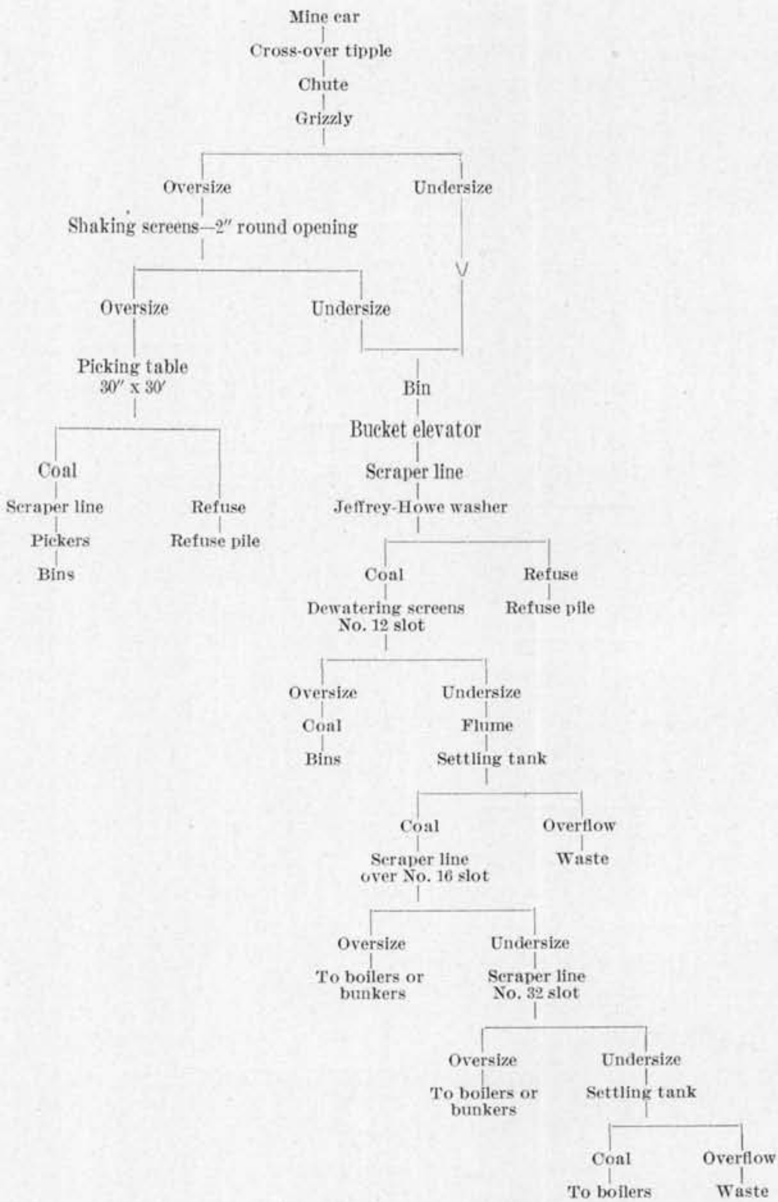
considered in this connection as one solution of the problem of disposing of fine coal.

In 1908 and 1909, the fuel testing plant of the United States Geological Survey at Denver carried on a series of washing and coking tests of coals.* Among the coals tested was a consignment of 50 tons of run-of-mine from the Number 3 Wilkeson bed at Carbonado. The results of the washing tests are tabulated on pages 113 and 114.

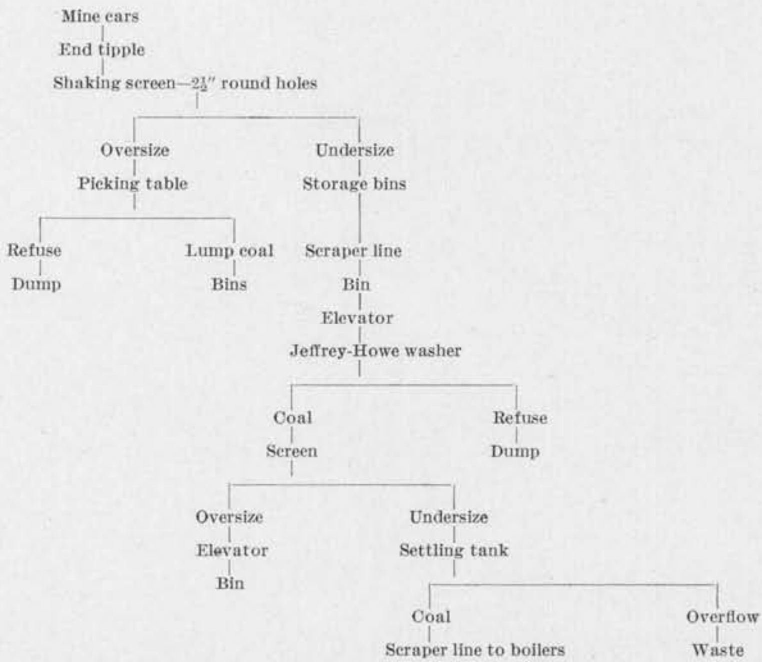
*"Washing and Coking Tests of Coal at the Fuel-testing Plant, Denver, Col., July 1, 1908, to June 30, 1909," by A. W. Belden and others. Bureau of Mines, Bulletin 5, pp. 15, 32-38, 1910.



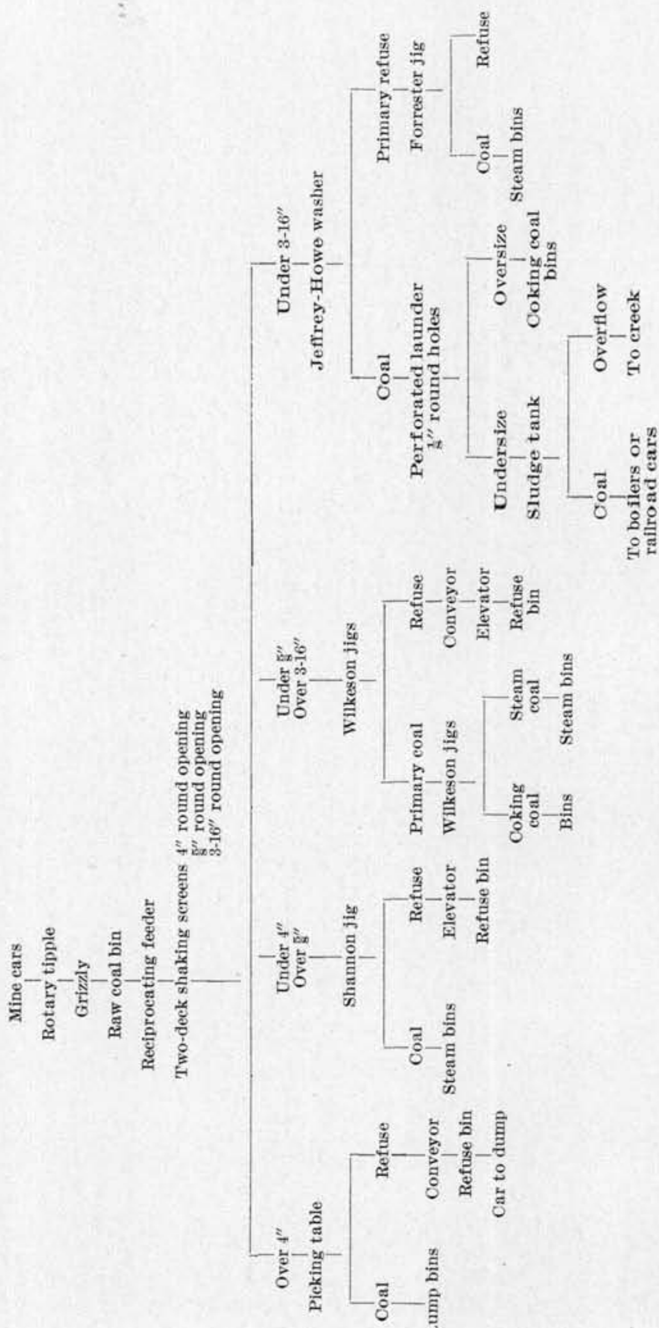
AMERICAN COAL COMPANY, SPIKETON.



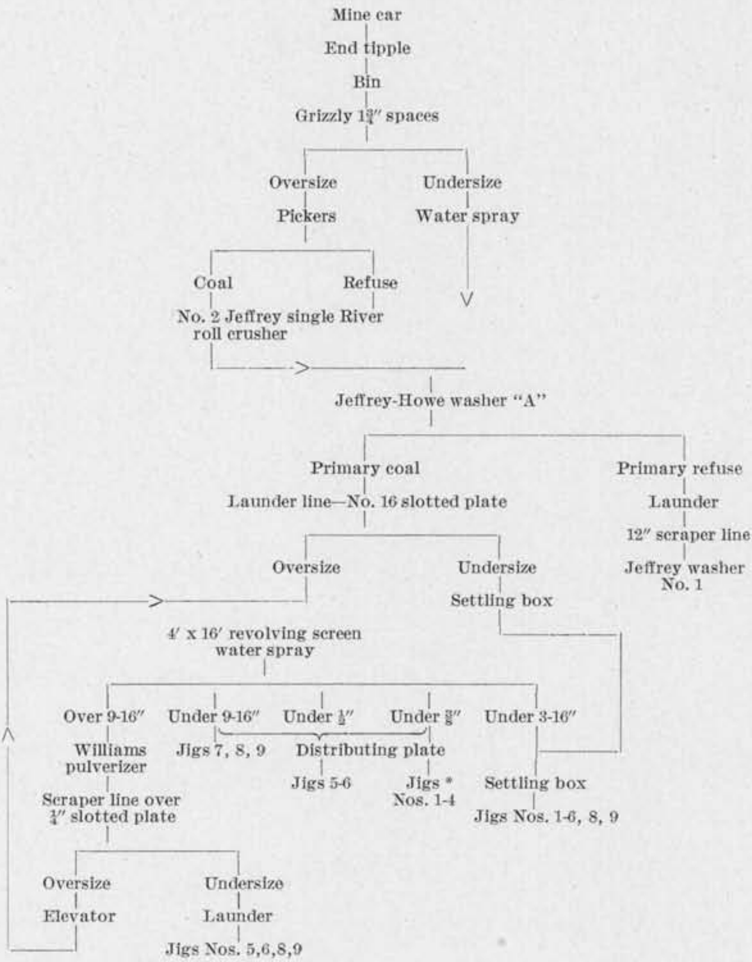
PACIFIC COAST COAL COMPANY, BURNETT MINE.



GALE CREEK COAL MINES COMPANY, WILKESON.



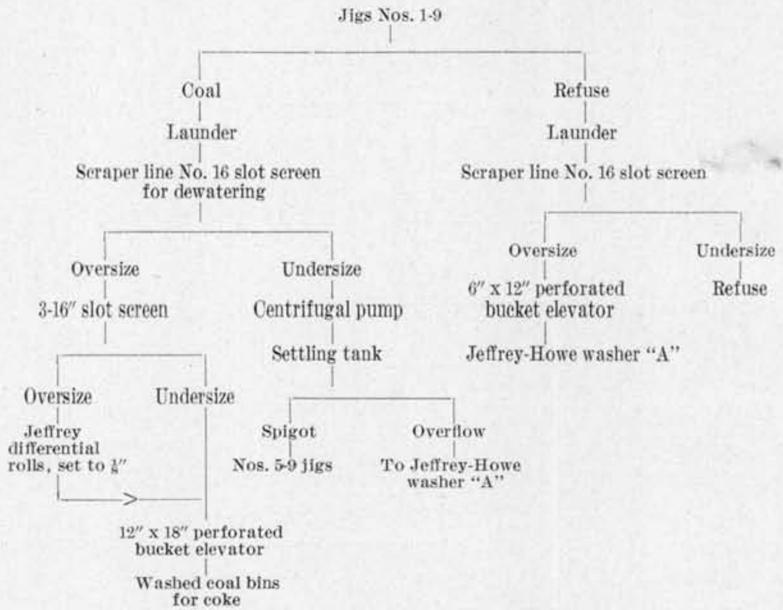
WILKESON COAL AND COKE COMPANY.



* Jigs are Luhrig type.

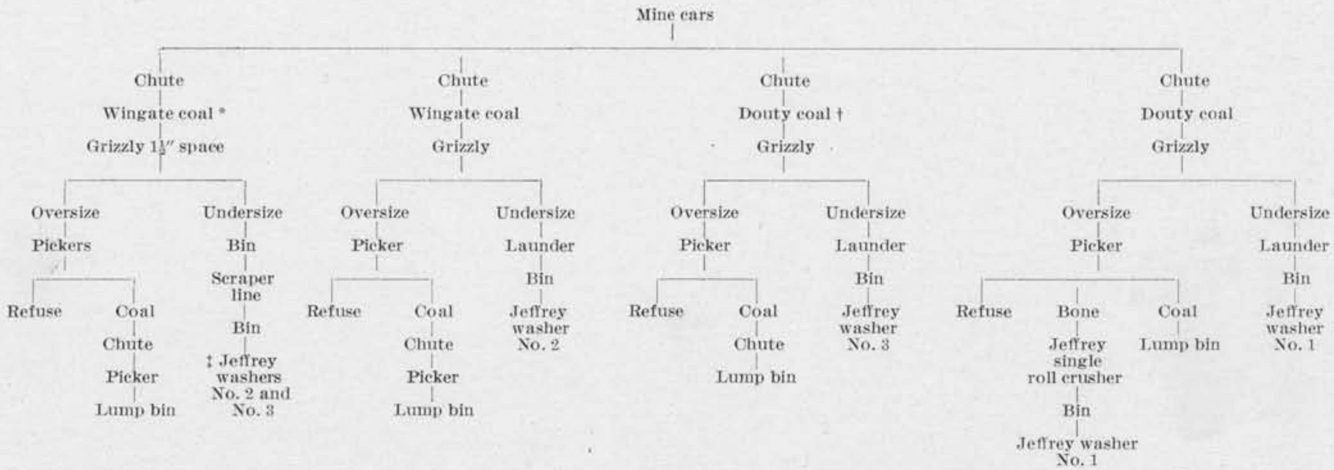
CARBON HILL COAL COMPANY, CARBONADO.

Coking Coal Washery.



CARBON HILL COAL COMPANY, CARBONADO.

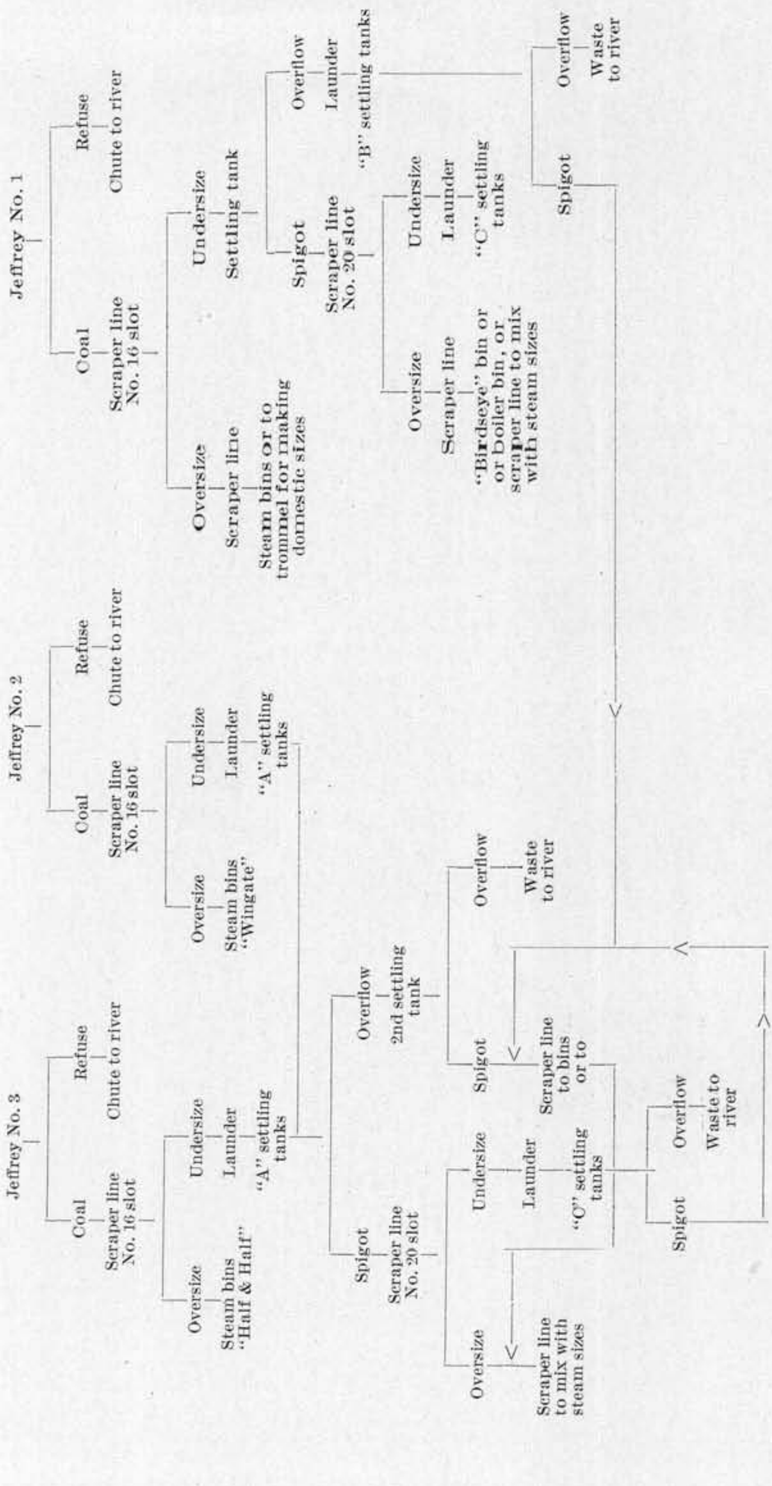
Coking Coal Washery (Continued).



* Wingate coal is Wingate and Miller.
† Douty coal is all other coal.
‡ All Jeffrey washers are of Howe type.

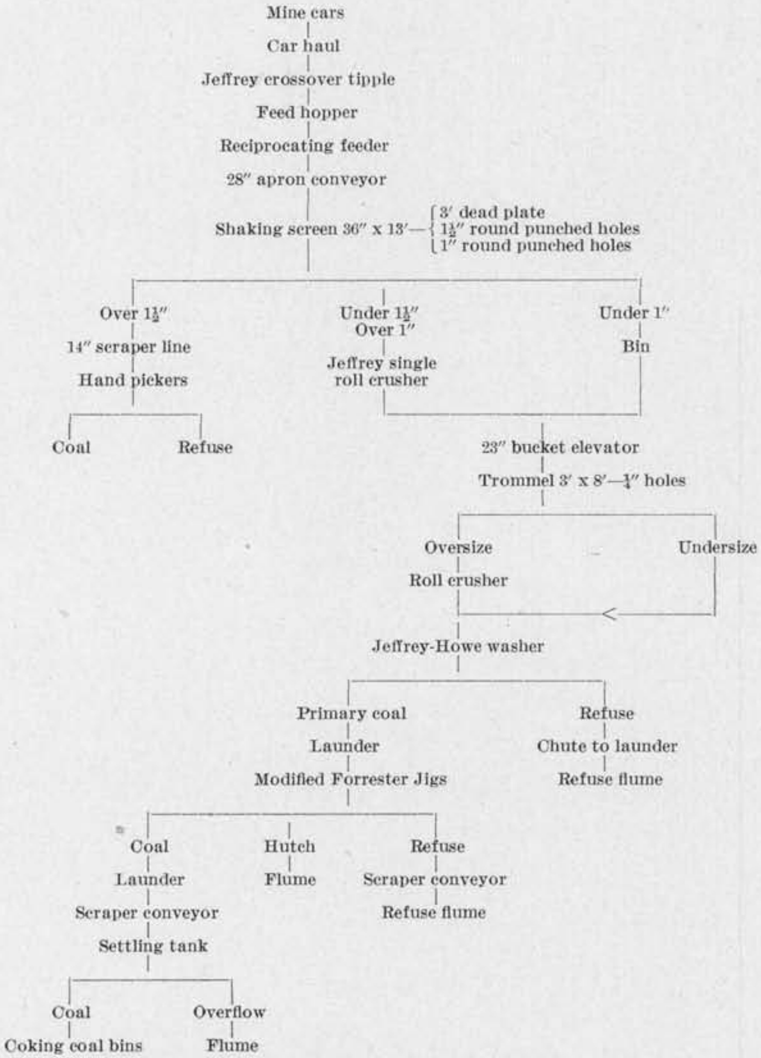
CARBON HILL COAL COMPANY, CARBONADO.

Lump and Steam Coal Washery.

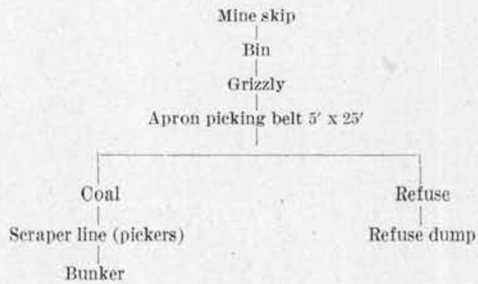


CARBON HILL COAL COMPANY, CARBONADO.

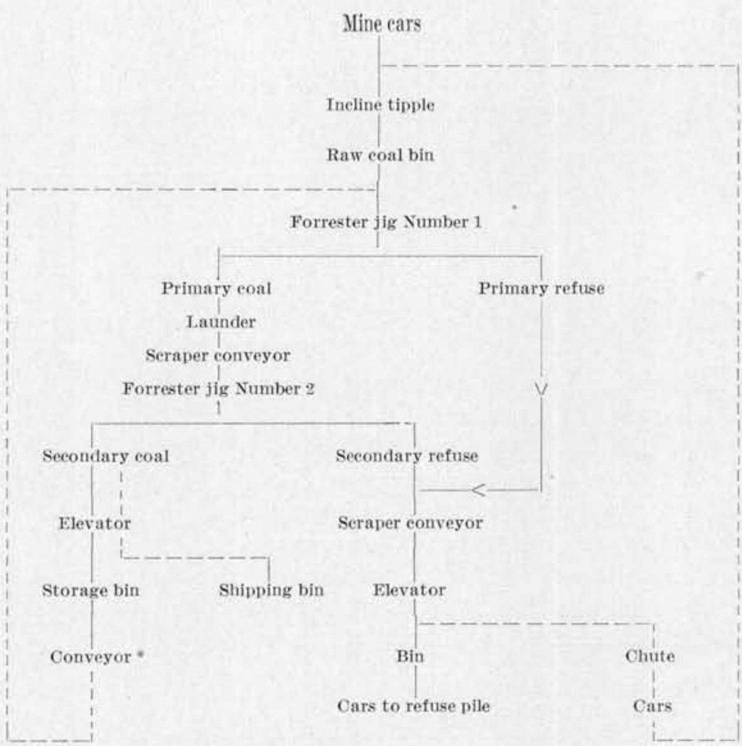
Lump and Steam Coal Washery (Continued).



FAIRFAX MINE, INC., SECTION 34, FAIRFAX.



NORTHWESTERN IMPROVEMENT COMPANY, MELMONT.



* Conveyor delivers to Forrester jig Number 1 and flow sheet is repeated for the rewashing except that the new refuse is taken by cars back to raw coal bin and rewashed and the product of the Forrester jig number 2 is shipped as indicated by dotted lines.

SOUTH WILLIS COAL COMPANY, SOUTH WILLIS.

TABLE I.—GENERAL DATA OF WASHING TESTS.

Denver No.	Test No.	Duration		Size of Coal		Jig Used		Raw coal used	Washed Coal		Refuse		Loss of good coal in refuse Per cent.
		H.	M.	As shipped	As washed	Name	Speed Rpm	Tons	Amount	Per cent.	Amount	Per cent.	
											Tons		
20....	264	4	40	Run of mine	¾ inch	Special	108	10.68	10.04	94	0.64	6	1
	265	2	40	Run of mine	¾ inch	Special	108	9.01	6.88	76	2.13	24	6
	266	5	20	Run of mine	¾ inch	Special	108	11.84	10.06	85	1.78	15	5

TABLE II.—ANALYSIS OF COALS—ON DRY BASIS.

Denver No.	Raw Coal				Washing Test No.	Washed Coal								Refuse			
								Ash			Sulphur						
	Volatile	Fixed carbon	Ash	Sulphur		Volatile	Fixed carbon	Per cent.	Per cent. of reduction	Per cent. removed	Per cent.	Per cent. of reduction	Per cent. removed	Volatile	Fixed carbon	Ash	Sulphur
20	....	....	....	....	264	32.43	53.21	14.36	14	34	0.58	....	4	21.38	22.65	55.97	.71
	30.49	52.77	16.74	0.47	265	31.36	54.84	13.80	18	37	0.57	....	9	....	No sample		.....
	....	....	....	....	266	32.68	55.52	11.80	30	55	0.56	....	23	23.64	30.85	45.51	.42

DENVER WASHING TESTS.

TABLE III.—RAW COAL FLOAT-AND-SINK TESTS.

Denver No.	Test No.	Maximum size of coal	Specific gravity of solution used	Percentage of		Float-Coal Analyses (dry basis)	
				Float	Sink	Ash	Sulphur
20	173	¾ inch	1.35	45	55	7.18	.46
	174	¾ inch	1.41	60	40	8.81	.51
	175	¾ inch	1.45	66	34	9.54	.48
	176	¾ inch	1.54	76	24	10.47	.51

TABLE IV.—REFUSE FLOAT-AND-SINK TESTS.

Denver No.	Refuse from washing test No.	Test No.	Specific gravity of solution used	Percentage of		Float-Coal Analyses (dry basis)	
				Float	Sink	Ash	Sulphur
20	264	189	1.35	4	96	7.98	1.06
		190	1.42	11	89	8.46	.87
		191	1.46	13	87	9.97	.93
		192	1.55	20	80	14.00	.84
	265	193	1.35	8	92	6.20	.90
		194	1.42	11	89	9.81	.89
		195	1.46	15	85	9.09	.93
		196	1.55	16	84	15.28	.72
	266	205	1.35	16	84	7.73	.48
		206	1.40	19	81	10.53	.69
		207	1.46	28	72	12.26	.54
		208	1.55	32	68	16.39	.56

TABLE V.—RAW COAL SCREENING TEST.

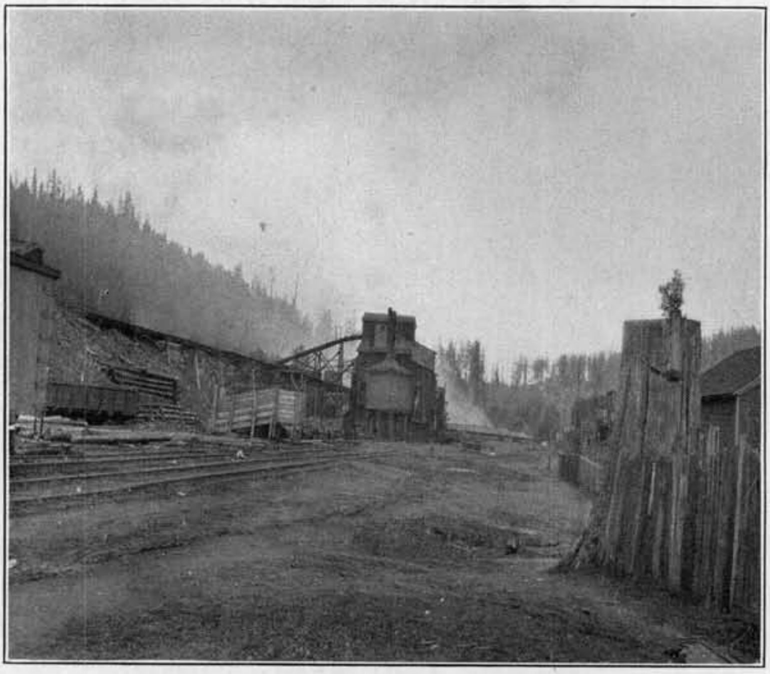
Denver No.	Over 1¼ inch	Through 1¼" and over 1"	Through 1" and over ¾"	Through ¾" and over ½"	Through ½" and over ⅜"	Through ⅜" and over ¼"	Through ¼"
20	....	....	2	14	7	21	56

DENVER WASHING TESTS.

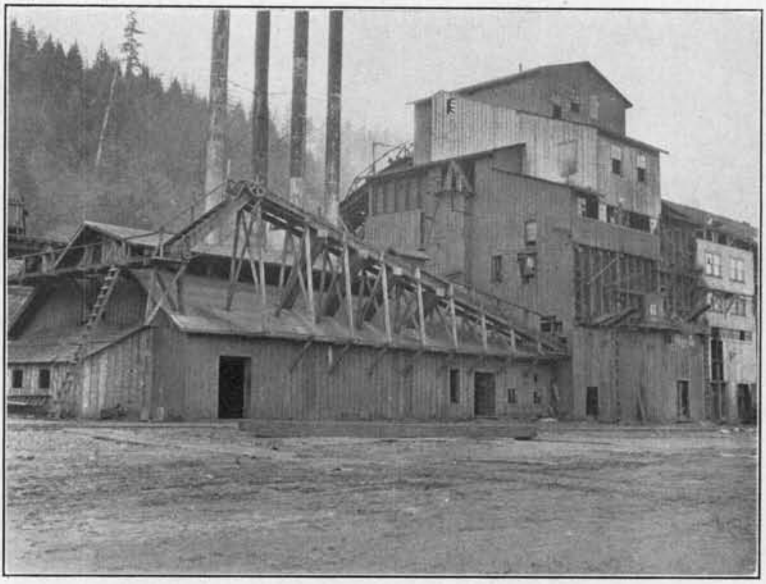
"The tests on Denver Number 20 compare fairly well with the float-and-sink tests, though they could be slightly improved with more careful jig adjustment."

A. Valley of South Prairie Creek, Burnett.

B. Tipple, Pacific Coast Coal Company, Burnett.



A. General View of Washer and Ovens. Wilkeson.



B. Boiler House and Washer, Wilkeson Coal & Coke Company.

CHAPTER VII.

COKING.

GENERAL STATEMENT.

The coking coals of Washington are the only ones of that grade on the Pacific Coast. The first coal coked in this state was made in 1884 in pits at the Tacoma Coal Company's property at Wilkeson. More pit coke was made in 1885 and in that year two ovens were built. [Plate XXVIII A.] Since that day the coking industry has been carried on continuously in Pierce County. Some of the northern coal districts of the state erected coal ovens and made coke but apparently were not successful, for we find these abandoned and since 1900 the field has been left entirely to the Pierce County operators. Table VI gives a summary of the statistics of the production of coke in the state from 1884 to 1912, together with data on the amount of coal used, the yield in coke, and the average values of the coke produced. Pierce County has 282 ovens, 232 of which are making coke at present.

Practically all of the coke is made from washed coal and no mine-run is used today, although in earlier days in the northern field this was attempted without success. The percentage of ash is higher than in eastern coke, ranging from 16 per cent upward, but sulphur and phosphorus are low. The coke made is firm, strong, and heavy, and is suitable for foundry and smelter purposes. At the present time this coke is mainly used at the Tacoma smelter, some is shipped to the California smelters, and some to the Granby smelter in British Columbia.

The ovens employed are all of the beehive type. [Plates XXVIII B and XXIX.] No by-product ovens are in use, although the possibilities of this method of coking have been considered. Some of the coals from the field are used in gas manufacture, yielding bench or retort coke which is sold for domestic consumption but which is not suitable for metallurgical purposes. The charges vary from 10,000 pounds for 48 hour coke

A. First Coke Ovens in Washington. Wilkeson.

B. Coke Oven Plant at Montezuma.

to 14,000 pounds for 72 hour coke, and the yields average between 60 and 63 per cent. Some 96 hour coke is made.

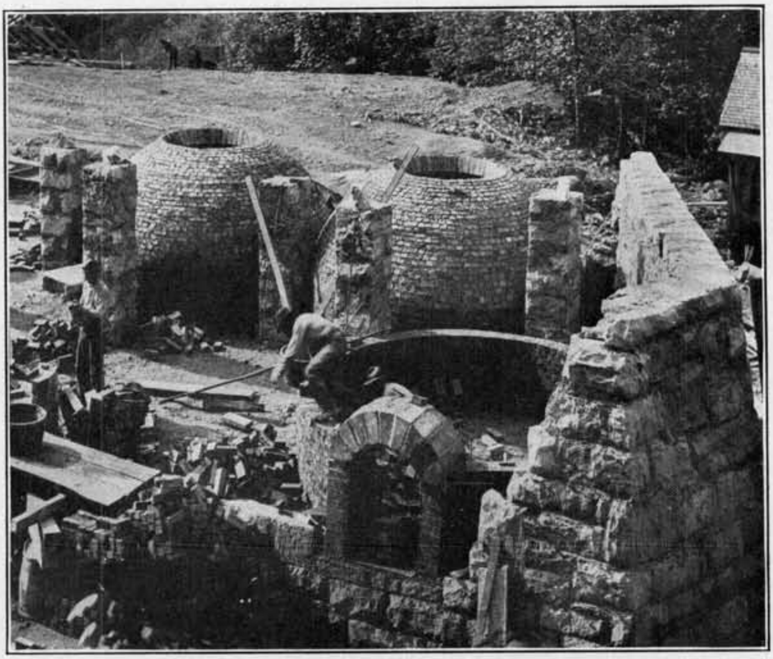
Results of the coking tests, already referred to, on the No. 3 Wilkeson seam from Carbonado are given in the following pages:

TABLE VI.

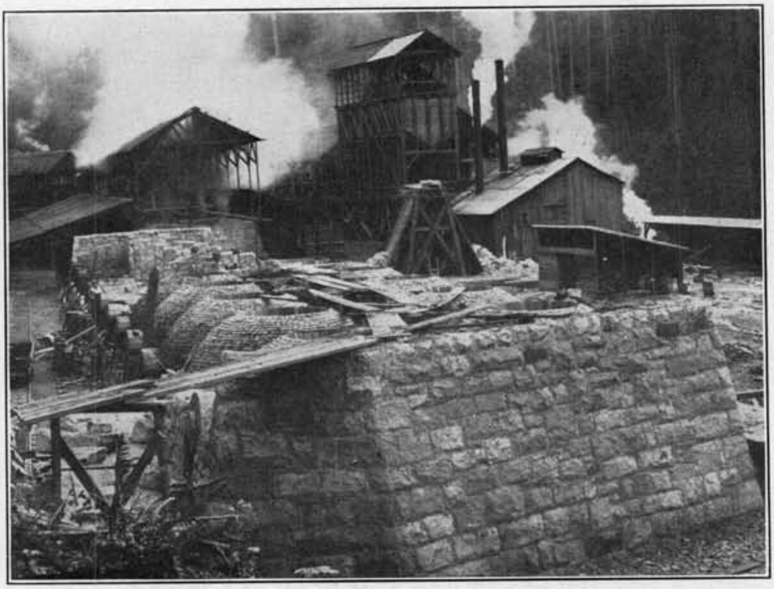
*STATISTICS OF THE PRODUCTION OF COKE IN WASHINGTON FROM 1884 TO 1913.

Year	Establishments	Ovens: Built	Ovens: Building	Coal used	Coke produced	Total value of coke at ovens	Value of coke at ovens per ton	Yield of coal in coke
				Short tons	Short tons			Per c't.
1884	1	0	0	700	400	$1,900	4.75	57.5
1885	1	2	0	544	311	1,477	4.75	57
1886	1	11	21	1,400	825	4,125	5.00	58.9
1887	1	30	0	22,500	14,625	102,375	7.00	65
1888	1	30	100	0	0	0	0	0
1889	1	30	0	6,983	3,841	30,728	8.00	55
1890	2	30	80	9,120	5,837	46,696	8.00	64
1891	2	80	0	10,000	6,000	42,000	7.00	60
1892	3	84	30	12,372	7,177	50,446	7.03	58
1893	3	84	0	11,374	6,731	34,207	5.08	59
1894	3	84	0	8,563	5,245	18,249	3.48	61.2
1895	3	110	0	22,973	15,129	64,632	4.27	65.9
1896	3	120	0	38,685	25,949	104,894	4.04	67
1897	3	120	0	39,124	26,189	115,754	4.42	67
1898	2	90	0	48,559	30,197	128,933	4.27	62.2
1899	2	90	0	50,813	30,372	151,216	4.98	59.8
1900	2	90	0	54,310	33,387	160,165	4.79	61.5
1901	4	148	100	78,393	49,197	239,028	4.84	62.7
1902	5	231	0	68,546	40,305	199,195	4.94	58.8
1903	6	256	0	73,110	45,623	214,776	4.71	62.4
1904	6	256	0	76,993	45,432	207,357	4.56	59
1905	5	216	0	85,715	53,137	251,717	4.74	62
1906	5	216	0	76,896	45,642	226,977	4.99	59.4
1907	5	216	0	85,860	52,028	293,019	5.63	60.6
1908	6	231	50	68,069	38,889	213,138	5.48	57.1
1909	6	285	0	69,708	42,981	240,604	5.60	61.7
1910	6	285	0	94,223	59,337	347,540	5.86	63.0
1911	5	235	0	60,201	40,180	216,262	5.38	66.6
1912	6	313	0	78,693	49,260	279,105	5.67	62.6
1913	....	....	....	....	....	....	....	....
				1,254,247	774,226			

* From U. S. Geological Survey Reports on Mineral Resources of the United States.



A. Carbonado. Coke Ovens Under Construction.



B. Carbonado. Coke Ovens and Coal Bins.

DENVER COKING TESTS.*

"The coking tests were carried on in two beehive ovens, (one 7 feet high by 12 feet in diameter, the other 6 feet 3 inches high by 12 feet in diameter). All coal was finely crushed through a Pennsylvania hammer crusher. The sampling of coal and the handling of the ovens were as follows:

Both the door and the trunnel head of the oven were always closed directly after the oven was drawn and it was allowed to gather heat, the length of time varying as necessity demanded. The average time was one and one-half hours.

The sample of coal was taken at regular intervals, as the charge was emptied from kiln to larry, by means of a small shovel holding about one-fourth pound. The total weight of the sample averaged 45 pounds.

The sample of coke was taken from five different parts of the oven, as nearly as possible from the same location for each test, as follows: 2 feet from the oven door; 2 feet from each side, on a line drawn from the center of the oven; at the center; and 2 feet from the back wall, on a line with the point of selection of the pieces taken from the door and the center. The separate pieces of coke extended the whole height of the charge and were as nearly uniform in size as possible.

The percentage of coke remaining on a screen with 2 inch mesh, after four consecutive six-foot drops without intermediate screening, as well as the percentage after each drop, is given in the last item under "Physical properties of coke." The first four items represent the percentage from each separate drop with all material less than 2 inch screened out, the fifth item the percentages after four consecutive drops, all material being returned each time. "Cell structure" refers to the general appearance as to size and not to the number of cells as given by percentage of cells by volume."

* Washing and Coking Tests of Coal at the Fuel-Testing Plant, Denver, Col., July 1, 1908, to June 30, 1909. Bureau of Mines, Bull. 5, pp. 15, 46, 47, 58.

TABLE VII.—COKING TESTS, DENVER NO. 20.

	287	288	289	290
Date	11-7-08	11-9-08	11-10-08	11-12-08
Duration—hours	38	44	72	44
Size,				
As shipped	* r. o. m.	r. o. m.	r. o. m.	r. o. m.
As used	w., n. c.	w., f. c.	w., f. c.	w., f. c.
Coal charged:				
Wet—pounds	10,580	12,400	16,300	12,300
Dry—pounds	9,607	11,463	15,139	11,643
Coke produced:				
Wet — pounds	6,654	7,950	10,350	8,100
Wet — per cent.	62.89	64.11	63.50	65.85
Dry — pounds	6,550	7,938	10,305	8,098
Dry — per cent.	68.18	69.25	68.07	69.55
Total yield:				
Wet ... per cent.	65.51	66.56	65.82	68.25
Dry ... per cent.	71.02	71.90	70.55	72.08
Physical properties of coke:				
Specific gravity				
Apparent	1.03	1.10	1.09	1.04
Real	1.95	1.99	1.97	1.97
Volume:				
Coke ... per cent.	53.00	55.00	55.00	53.00
Cells ... per cent.	47.00	45.00	45.00	47.00
Weight per cubic foot:				
Wet ... pounds	92.54	96.55	95.75	94.11
Dry ... pounds	63.25	68.47	67.67	64.81
6′ drop test over 2″ mesh:				
1	97.50	98.50	97.00	98.00
2	95.00	98.00	94.00	96.00
3	93.50	96.50	92.50	93.50
4	91.00	95.00	88.00	91.00
5	93.50	97.50	93.00	92.50

* r. o. m., run of mine.
w., n. c., washed, not crushed.
w., f. c., washed, finely crushed.

REMARKS: Tests 287 and 288: Light gray and silvery. Breakage good. Cell structure a little small. Good, strong, heavy coke.

Tests 289 and 290: Light gray and silvery, large deposit of carbon. Breakage good; long, large pieces. Cell structure small, dense. Metallic ring. Good, hard, strong, heavy coke.

TABLE VIII.—CHEMICAL ANALYSES.

Test No.	Laboratory No.			Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Phosphorus
287	786-D	Coal	Wet	9.20	29.12	49.86	11.82	0.51	
			Dry	....	32.07	54.91	13.02	.56	
	790-D	Coke	Wet	1.57	2.03	78.11	18.29	.57	.0460
			Dry	....	2.06	79.39	18.55	.58	
288	788-D	Coal	Wet	7.56	30.32	47.61	14.51	.56	
			Dry	....	32.79	51.51	15.70	.61	
	794-D	Coke	Wet	.15	.16	79.51	20.18	.60	.0477
			Dry	....	.16	79.63	20.21	.60	
289	791-D	Coal	Wet	7.12	29.12	50.94	12.82	.53	
			Dry	....	31.36	54.84	13.80	.57	
	799-D	Coke	Wet	.43	2.81	76.80	19.96	.55	.0579
			Dry	....	2.82	77.14	20.04	.55	
290	795-D	Coal	Wet	5.34	30.93	52.57	11.16	.53	
			Dry	....	32.68	55.52	11.80	.56	
	801-D	Coke	Wet	.03	.71	80.99	18.27	.44	.0481
			Dry	....	.71	81.02	18.27	.44	

A. Miners' Homes, Burnett.

B. Carbonado Townsite.

CHAPTER VIII.

ECONOMIC CONSIDERATIONS.

TRANSPORTATION.

The Northern Pacific Railway taps the various mines by a series of branches and spurs which unite all of the towns. The principal coal branch line joins the Buckley branch at South Prairie, but another branch which serves the shipping bunkers at Carbonado follows down the Carbon River to Crocker on the Buckley branch. This branch connects with the main line at Puyallup and gives direct service to tide water at Tacoma and Seattle.

MARKETS.

The principal market for Pierce County coal is in western Washington, both for local consumption and for the steamship trade. The steamship trade may be divided into the coastwise and the foreign. Some coal is shipped to Oregon and Alaska and during the past year the strike in British Columbia opened a temporary market in that province for Washington coal. The coke is used for local foundry purposes, the Tacoma smelter takes a considerable portion, some is shipped to the smelters in California and a new market has been opened in the new Granby smelter at Anyox, British Columbia. Very little coal, if any, is sold east of the Cascades.

Coal in western Washington is used mainly for steam generation, domestic consumption, coke manufacture and the production of illuminating gas. Cheap electric power and the competition of California oil have served to reduce the local demand for steam coal and have practically eliminated the trade with nearby states. The demand for coal for domestic uses is fairly steady, although subject to seasonal variations due to Puget Sound weather. The constantly increasing use of electricity in the home for both cooking and lighting affects not only the domestic trade but also the demand for coal for gas making. The retort coke manufactured in the process is not suitable for metallurgical purposes and can only have a limited use in industry for power production and some domestic use. Beehive oven coke will always be in demand because there is no other source on the coast than in this state. As far as can be learned, no Washington coal is used in the chemical or metallurgical industries, except in connection with the illuminating gas industry. Very little coal is used in gas-producer plants, although this field of operation opens many attractive possibilities, and there are no by-product coke ovens on the Pacific coast.

The coal trade is capable of great expansion. Most of the mines are equipped to give greater outputs than the markets demand, but the plants are idle during many days of the year and the operating efficiency is, therefore, low. The waste in mining and washing is very high, and only the higher grade coals may be worked. The coals high in ash and much of the refuse made in washing could be economically used in gas producers either for fuel or for power in internal combustion engines. By-product producer plants would solve the problem of removing the valuable chemical components and giving the gas better value as heat and power producers. Undoubtedly some of the finer sizes of coal which are now wasted in washing can be sold at a figure which will offer inducements to power plants to install proper burning devices. Whether briquetting, as an industry utilizing these coals, succeeds will depend largely on the cost of manufacture of merchantable product. At the present time one company is manufacturing briquettes from Washington coal.

In the field of by-product coking the question is largely one of economics, involving the distribution and sale of the gas and the development of chemical industries to work up the tars and oils and other valuable products. The Pierce County coal meets the requirements of a metallurgical coke, at present largely used in copper and lead smelting and in foundry work, and there seems little doubt that it will be satisfactory coke for the manufacture of iron in blast furnaces.

OPERATION FACTORS.

The influence of railroad building in the development of a coal field is most clearly seen in the case of Pierce County. The Northern Pacific Railway had built its line to Tacoma and the branch to Wilkeson in 1876, giving this locality an early start ahead of its neighbors in King and Kittitas counties. The result is evidenced in the steady development of the mines in this field which were opened at this time and the practical limitation of the area of operations to points served by the railroad. Although geologic influences have had a great share in determining where mines shall be opened, the question of railroad transportation has been equally important, and today we find operating mines only at those points in the northern part of the county where both factors have been favorable.

The heavy forests supply an abundance of timber for mining, which is a factor of great importance in the mining of steep dipping seams of variable structure. The methods of mining now in operation insure a high recovery of coal, except for the mechanical losses involved when the coal is removed in drawing pillars. This would not be possible without an adequate supply of low-priced timber.

Labor conditions have generally been favorable in this field. In the early days some Chinese were employed in the mines but these soon gave way to white labor, which rules today. Occasional labor disputes and strikes have occurred, but they were of short duration and have never completely tied up the industry. The field, as a whole, is organized under the jurisdiction of the United Mine Workers of America, and wages and conditions of labor are fixed by agreement with the coal operators' association. Climate and living conditions are far superior to many of the coal fields of the country, and wages are the highest of any in the United States. Just as wages are high, so is the average price per ton of coal at the mines of the state, which for 1912 is given as $2.39, the highest figure for any state except Oregon, which has a very limited production. The average number of days worked in the producing mines in

1913 was 275 and the number of men employed was 1562. Six men were killed and 244 injured.

PRODUCTION RECORDS.

Records of production of coal are given in the appendix. The figures for coal have been compiled from the reports of the State Inspectors of Coal Mines. These figures do not exactly tally with the figures given by the U. S. Geological Survey in Mineral Resources of the United States, which are given in the table on this page. Pierce County ranks third among the coal producers of the state, being surpassed by Kittitas and King counties. In coke production Pierce leads all counties, and at the present time is the only coke producer on the coast.

TABLE OF COAL PRODUCTION, PIERCE COUNTY, 1884 TO 1912.*

Years.	*Short Tons.*
Jan. 1, 1884-Nov. 1, 1884	267,884
1886	199,252
1887	229,785
1888	276,956
1889	273,618
1890	285,886
1891	271,053
1892	364,294
1893	408,074
1894	406,831
1895	437,029
1896	419,568
1897	458,394
1898	509,142
1899	506,385
1900	577,127
1901	585,984
1902	383,603
1903	572,800
1904	531,589
1905	479,912
1906	513,639
1907	572,169
1908	551,678
1909	609,467
1910	786,096
1911	783,196
1912	788,293
	13,049,704

* From U. S. Geological Survey Reports on Mineral Resources of the United States.

FUTURE PROSPECTS.

The development of the Pierce County field will continue along the lines already established by the older producing companies. Mines already in operation will extend their workings to lower levels and in some cases will open up new seams, but the main lines of attack are already fixed. New mines may be opened, but the number will be few and these will be confined to the northern part of the county. Although large areas of coal-bearing sedimentaries are present in the Puyallup-Nisqually area in the southern part of the county, these coals are of inferior grade, they are more disturbed structurally, and transportation is lacking. These factors alone, even without the others which have served to define the line of operations in the Wilkeson-Carbonado field, would be sufficient to hold back the exploitation of these southern areas.

In addition to the factors already discussed, one or two others have an important place in determining the future of this field. California oil is rapidly displacing coal in steam plants, both on land and on steamships. Railroads, power plants, and industrial plants are substituting the cheaper oil for the more expensive coal. The balance in economy is still, theoretically in favor of oil and will probably continue for some time. This means that the market for steam coal will diminish, and the domestic coals will have to make up for the lessened demand. Steam coal may recover part of its loss if its heat content is increased by more careful washing, and the domestic market will only be maintained so long as the coal sets a better standard than competing coals. But the coking coals furnish the greatest ray of hope in the consideration of the future. So long as a demand exists for metallurgical coke this field will continue to maintain a steady production, and unless the higher grade Alaska coals replace it, coke made in Pierce County will find a constantly increasing market in the industries of the Pacific Coast.

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APPENDIX A.

PIERCE COUNTY COALS.—TABLE OF CHEMICAL ANALYSES.*

LOCALITY, BED, ETC.	SAMPLE †			PROXIMATE				ULTIMATE					Air-drying loss	CALORIFIC VALUE	
	Laboratory No.	Kind	Condition	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen		Calories	British thermal units
Ashford, sec. 22, T. 15 N., R. 6 E., Mashel mine, end of gangway, 4,400 feet from entrance (lower bench, 61-inch cut).	9,884	B	1	4.11	24.38	44.75	26.76	.44	4.31	58.16	1.39	8.94	2.6	5,719	10,294
			2	......	25.43	46.66	27.91	.46	4.02	60.66	1.45	5.50	......	5,964	10,735
			3	......	35.28	64.72	......	.64	5.58	84.15	2.01	7.62	......	8,273	14,891
Same (upper bench, 10 feet 5½ inches, 9-foot 9½-inch cut).	9,885	B	1	4.02	22.00	35.94	38.04	.68	3.69	46.95	1.27	9.37	2.4	4,671	8,408
			2	......	22.92	37.45	39.63	.71	3.38	48.92	1.32	6.04	......	4,867	8,761
			3	......	37.97	62.03	......	1.81	5.60	81.04	2.19	9.99	......	8,062	14,512
7 miles of sec. 20, T. 15 N., R. 7 E., Longmire prospect (39-inch cut).	6,486	B	1	9.41	12.78	51.31	26.50	.37	......	......	......	......	7.0	5,251	9,452
			2	......	14.11	56.64	29.25	.41	......	......	......	......	......	5,797	10,435
			3	......	19.94	80.06	......	.58	......	......	......	......	......	8,193	14,747
Burnett, sec. 16, T. 19 N., R. 6 E., Burnett mine, level 2 (washed, still wet, from bunkers and car).	9,886	B	1	7.72	34.36	46.57	11.35	.56	5.69	67.50	1.88	13.02	6.1	6,838	12,308
			2	......	37.24	50.47	12.29	.61	5.23	73.15	2.04	6.68	......	7,410	13,338
			3	......	42.46	57.54	......	.70	5.96	83.40	2.33	7.61	......	8,448	15,206
Same (lump, from bunkers)............................	9,887	B	1	3.25	36.79	46.81	13.15	.41	5.31	68.77	1.95	10.41	1.4	6,961	12,530
			2	......	38.03	48.38	13.59	.42	5.12	71.08	2.02	7.77	......	7,195	12,951
			3	......	44.01	55.99	......	.49	5.93	82.25	2.34	8.99	......	8,327	14,989
Same (north end of gangway, 1,650 feet north on rock tunnel, No. 3 bed, lower bench, 67-inch cut).	9,888	B	1	4.65	35.23	46.93	13.19	.37	5.36	67.64	1.93	11.51	2.7	6,818	12,272
			2	......	36.95	49.22	13.83	.39	5.08	70.94	2.02	7.74	......	7,150	12,870
			3	......	42.88	57.12	......	.45	5.90	82.33	2.34	8.98	......	8,298	14,936
Same (position and bed same as No. 9,888, upper bench, 18-inch cut).	9,889	B	1	3.61	36.83	45.47	14.09	.38	5.36	67.76	1.75	10.66	1.8	6,872	12,370
			2	......	38.21	47.17	14.62	.39	5.15	70.29	1.82	7.73	......	7,129	12,832
			3	......	44.75	55.25	......	.46	6.03	82.32	2.13	9.06	......	8,349	15,028
Same (15 feet above gangway, manway south of rock tunnel, No. 3 bed, 6 feet, 4½-foot cut).	9,890	B	1	3.20	35.02	49.32	12.46	.38	5.28	70.74	1.97	9.17	1.3	7,066	12,719
			2	......	36.18	50.96	12.86	.39	5.08	73.08	2.04	6.55	......	7,300	13,140
			3	......	41.52	58.48	......	.45	5.83	83.87	2.34	7.51	......	8,378	15.080

* Table taken from Analyses of Coals in the United States, Bull. 22, Part I, Bureau of Mines, 1913, which is based on tables in Coals of the State of Washington, E. Eggleston Smith, Bull. 474, U. S. Geological Survey, 1911.

† The kind of sample is denoted by letter, as follows: A—mine sample collected by an inspector of the technologic branch of the Survey; B—mine sample collected by a geologist of the Survey; C—car sample taken at the fuel-testing plant. The form of analysis is denoted by number, as follows: 1—sample as received; 2—dried at temperature of 105°C; 3—moisture and ash free.

PIERCE COUNTY COALS.—TABLE OF CHEMICAL ANALYSES.—Continued.

LOCALITY, BED, ETC.	SAMPLE			PROXIMATE				ULTIMATE					Air-drying loss	CALORIFIC VALUE	
	Laboratory No.	Kind	Condition	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen		Calories	British thermal units
Burnett, Burnett mine (Concluded).															
Same (crosscut 1, 2,200 feet south of rock tunnel, No. 2, bed, 50½ inches, 3¾ foot cut).	9,891	B	1	3.69	36.04	52.14	8.13	.76	5.56	73.89	2.00	9.66	2.4	7,540	13,572
			2	......	37.42	54.14	8.44	.79	5.35	76.72	2.08	6.62	......	7,829	14,092
			3	......	40.87	59.13	......	.86	5.84	83.79	2.27	7.24	......	8,551	15,392
Carbonado, sec. 4, T. 18 N., R. 6 E., Carbon Hill mines, west side of syncline, chute No. 11, 3,000 feet from tipple at Carbon River (No. 1, 84¼-inch bed, 63-inch cut).	2,460	B	1	4.06	31.16	50.19	14.50	.35	......	......	......	......	2.4	......	......
			2	......	32.48	52.31	15.21	.36	......	38.31	61.69	.42	......	......	......
				......	38.31	61.69	......	.42	......	......	......	......	......	......	......
Same (1,000 feet from slope, on level 700 feet below the river near a small fault, Wingate bed, 59-inch cut).	2,459	B	1	3.47	39.87	50.41	6.25	.86	......	44.16	55.84	.95	1.4	......	......
			2	......	41.30	52.23	6.47	.89	......	......	......	......	......	......	......
			3	......	44.16	55.84	......	.95	......	......	......	......	......	......	......
Same (south end of gangway, No. 3 coking bed, lower bench, 103 inches, 6-foot cut).	9,555	B	1	3.81	26.60	49.33	20.26	.39	5.01	63.85	1.93	8.56	3.0	6,399	11,518
			2	......	27.65	51.29	21.06	.41	4.77	66.38	2.01	5.37	......	6,652	11,974
			3	......	35.03	64.97	......	.52	6.04	84.09	2.55	6.80	......	8,427	15,169
Same (end of gangway on water level, 400 feet from entrance, No. 9 bed, 43-inch cut).	9,556	B	1	3.74	29.00	51.76	15.50	.52	5.08	67.37	2.13	9.40	2.4	6,739	12,130
			2	......	30.13	53.77	16.10	.54	4.84	69.99	2.21	6.32	......	7,001	12,602
			3	......	35.91	64.09	......	.64	5.77	83.42	2.63	7.54	......	8,344	15,019
Same (end of right gangway, No. 2 coking bed, 8 feet 9¼ inches, 101¾-inch cut).	9,557	B	1	3.84	37.05	53.74	15.37	.39	4.99	68.20	2.02	9.03	2.8	6,852	12,334
			2	......	28.13	55.89	15.98	.41	4.74	70.92	2.10	5.85	......	7,125	12,875
			3	......	33.48	66.52	......	.49	5.64	84.41	2.50	6.96	......	8,480	15,264
Same (first crosscut above level 3, 20 feet off slope to north, No. 6 mine, Wingate bed, 61-inch cut).	9,558	B	1	4.00	36.85	52.74	6.41	.52	5.84	74.02	2.16	11.05	2.0	7,380	13,284
			2	......	38.39	54.93	6.68	.54	5.63	77.11	2.25	7.79	......	7,688	13,838
			3	......	41.14	58.86	......	.58	6.03	82.63	2.41	8.35	......	8,238	14,828
Same (from bins and railroad cars, over 2-inch screen, washed and still wet, Douty coal).	9,559	C	1	5.83	30.59	49.93	13.65	.42	5.34	66.54	1.92	12.13	4.6	6,707	12,073
			2	......	32.48	53.03	14.49	.45	4.98	70.66	2.04	7.38	......	7,122	12,820
			3	......	37.99	62.01	......	.53	5.82	82.64	2.39	8.62	......	8,329	14,993
Same (samples from north and south ends of level 3 gangway mixed, Wingate bed, 54-inch cut).	9,560	B	1	2.74	36.31	52.83	8.12	.49	5.80	74.07	2.10	9.42	1.5	7,521	13,538
			2	......	37.33	54.32	8.35	.50	5.56	76.16	2.16	7.17	......	7,733	13,919
			3	......	40.73	59.27	......	.55	6.18	83.10	2.36	7.81	......	8,437	15,187
Same (200 feet up chute 14, No. 4 bed, 82½ inches, 64½-inch cut).	9,562	B	1	3.19	34.84	51.54	10.43	.32	5.48	72.54	1.89	9.34	2.0	7,340	13,212
			2	......	35.99	53.24	10.77	.33	5.30	74.93	1.95	6.72	......	7,582	13,648
			3	......	40.33	59.67	......	.37	5.94	83.97	2.19	7.53	......	8,497	15,295
Same (over 3-inch bar screen, Wingate bed)...............	9,563	C	1	3.07	37.17	51.81	7.95	.44	......	......	......	......	1.8	7,553	13,595
			2	......	38.35	53.45	8.20	.45	......	......	......	......	......	7,792	14,026
			3	......	41.77	58.23	......	.49	......	......	......	......	......	8,488	15,278

LOCALITY, BED, ETC.	SAMPLE			PROXIMATE				ULTIMATE					Air-drying loss	CALORIFIC VALUE	
	Laboratory No.	Kind	Condition	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen		Calories	British thermal units
Carbonado, Carbon Hill mines (Continued).															
Same (end of gangway on water level, 3,200 feet south of portal, No. 5 bed, 84½-inch cut).	9,564	B	1	3.60	29.73	50.29	16.38	.56	4.94	65.52	2.10	10.50	1.9	6,504	11,707
			2	......	30.84	52.17	16.99	.58	4.71	67.96	2.18	7.58	......	6,747	12,145
			3	......	37.15	62.85	......	.70	5.67	81.87	2.63	9.13	......	8,128	14,630
Same (lump, from car, Wingate bed)	9,566	C	1	3.18	34.52	51.56	10.74	.69	5.32	71.46	1.97	9.82	1.7	7,251	13,052
			2	......	35.65	53.26	11.09	.71	5.13	73.80	2.03	7.24	......	7,489	13,480
			3	......	40.10	59.90	......	.80	5.77	83.00	2.28	8.15	......	8,423	15,161
Same (end of rock tunnel, No. 1 coking bed, 29 inches, 2⅓-foot cut).	9,569	B	1	2.83	28.07	50.77	18.33	3.22	4.78	65.62	1.89	6.16	2.2	6,686	12,037
			2	......	28.89	52.25	18.86	3.31	4.59	67.53	1.94	3.77	......	6,881	12,386
			3	......	35.60	64.40	......	4.08	5.66	83.22	2.39	4.65	......	8,479	15,262
Same (40 feet above gangway, 500 feet from entrance, No. 11 bed, 53 inches, 37½-inch cut).	9,570	B	1	4.45	28.45	47.59	19.51	.39	4.85	62.34	1.78	11.13	2.7	6,261	11,270
			2	......	29.78	49.80	20.42	.41	4.56	65.25	1.86	7.50	......	6,553	11,795
			3	......	37.42	62.58	......	.52	5.73	81.99	2.34	9.42	......	8,234	14,821
Same (Douty lump from bins and cars, still moist)	9,571	C	1	3.53	30.58	48.18	17.71	.40	......	......	......	......	2.3	6,460	11,628
			2	......	31.70	49.94	18.36	.41	......	......	......	......	......	6,697	12,055
			3	......	38.83	61.17	......	.50	......	......	......	......	......	8,203	14,764
Same (level 1, 100 feet up chute 13, 600 feet north of bottom of electric slope, No. 1 bed, 88 inches, 77-inch cut).	9,572	B	1	3.38	32.21	49.53	14.88	.45	5.33	67.24	2.00	10.10	1.8	6,804	12,247
			2	......	33.34	51.26	15.40	.47	5.12	69.59	2.07	7.35	......	7,042	12,676
			3	......	39.41	60.59	......	.56	6.05	82.26	2.45	8.68	......	8,324	14,983
Same (crosscut 10 between chutes 56 and 57, level 2, Wingate bed, 49-inch cut).	9,601	B	1	2.85	32.84	53.66	10.65	1.11	5.38	70.92	1.80	10.14	1.1	7,142	12,856
			2	......	33.80	55.24	10.96	1.14	5.21	73.00	1.85	7.84	......	7,351	13,232
			3	......	37.96	62.04	......	1.28	5.85	81.99	2.08	8.80	......	8,256	14,861
Same (main entry 3 north, 1,400 feet west, 89-inch cut)	552D	A	1	2.90	30.94	50.12	16.04	.46	......	......	......	......	1.8	6,907	12,433
			2	......	31.87	51.61	16.52	.47	......	......	......	......	......	7,117	12,810
			3	......	38.18	61.82	......	.56	......	......	......	......	......	8,525	15,345
Same (car sample)	787D	C	1	4.66	29.07	50.31	15.96	.45	4.95	67.18	2.11	9.35	3.3	6,740	12,132
			2	......	30.49	52.77	16.74	.47	4.65	70.47	2.21	5.46	......	7,070	12,726
			3	......	36.62	63.38	......	.56	5.59	84.64	2.65	6.56	......	8,491	15,285
Same (from cars, washed, still wet)	9,561	C	1	3.70	32.36	51.49	12.45	.76	5.12	69.16	2.03	10.48	2.5	7,028	12,650
			2	......	33.60	53.47	12.93	.79	4.89	71.82	2.11	7.46	......	7,298	13,136
			3	......	38.59	61.41	......	.91	5.62	82.49	2.42	8.56	......	8,382	15,088
Same (south end of gangway, No. 3 coking bed, upper bench, 17-inch cut).	9,565	B	1	4.18	29.99	52.39	13.44	.30	5.10	70.13	1.88	9.15	3.5	7,034	12,661
			2	......	31.30	54.67	14.03	.31	4.84	73.19	1.96	5.67	......	7,341	13,214
			3	......	36.41	63.59	......	.36	5.63	85.12	2.28	6.61	......	8,538	15,368

LOCALITY, BED, ETC.	SAMPLE: Laboratory No.	SAMPLE: Kind	SAMPLE: Condition	PROXIMATE: Moisture	PROXIMATE: Volatile matter	PROXIMATE: Fixed carbon	PROXIMATE: Ash	ULTIMATE: Sulphur	ULTIMATE: Hydrogen	ULTIMATE: Carbon	ULTIMATE: Nitrogen	ULTIMATE: Oxygen	Air-drying loss	CALORIFIC VALUE: Calories	CALORIFIC VALUE: British thermal units
Spiketon, Spiketon mine (Concluded).															
Spiketon mine (from bins and cars, washed)........	9,893	C	1	7.79	31.27	40.53	20.41	.40	5.08	57.19	1.65	15.32	4.7	5,708	10,274
			2	......	33.91	43.96	22.13	.43	4.51	62.02	1.79	9.12	......	6,190	11,142
			3	......	43.55	56.45	....	.55	5.79	79.65	2.30	11.71	......	7,947	14,305
Same (gangway just beyond chute 13½, level 1, Pittsburg bed, 56⅝ inches, 50¼-inch cut).	9,894	B	1	4.69	32.71	42.22	20.38	.55	4.86	59.19	1.84	13.18	2.2	6,031	10,856
			2	......	34.32	44.30	21.38	.58	4.55	62.10	1.93	9.46	......	6,328	11,390
			3	......	43.65	56.35	....	.74	5.79	78.98	2.45	12.04	......	8,049	14,488
Same (crosscut 1, between chutes 32½ and 33, level 1, Lady Wellington bed, 59-inch cut).	9,895	B	1	6.67	32.75	42.11	18.47	.41	5.00	58.85	1.64	15.63	3.5	5,911	10,640
			2	......	35.09	45.12	19.79	.44	4.56	63.06	1.76	10.39	......	6,334	11,401
			3	......	43.75	56.25	....	.55	5.68	78.63	2.19	12.95	......	7,897	14,215
South Willis, 2 miles from Wilkeson: sec. 22, E. 19 N., R. 6 E., South Willis mine, Winsor bed (lower water-level gangway, 25 feet beyond chute 11, 4½-foot cut).	9,906	B	1	3.15	30.17	45.50	21.18	.41	4.82	62.56	1.56	9.47	1.4	6,243	11,237
			2	......	31.15	46.98	21.87	.42	4.62	64.59	1.61	6.89	......	6,446	11,603
			3	......	39.87	60.13	....	.54	5.91	82.67	2.06	8.82	......	8,250	14,850
Same (from bunkers, washed)........	9,907	C	1	7.07	28.39	42.03	22.51	.43	5.13	57.93	1.45	12.55	5.0	5,769	10,384
			2	......	30.55	45.23	24.22	.46	4.67	62.34	1.56	6.75	......	6,208	11,174
			3	......	40.31	59.69	....	.61	6.16	82.26	2.06	8.91	......	8,192	14,746
Wilkeson, sec. 28, T. 19 N., R. 6 E.; Brier Hill mine (500 feet south of water-level portal, 54-inch cut).	9,897	B	1	4.71	29.78	37.01	28.5	1.15	4.30	52.42	1.74	11.89	2.3	5,298	9,536
			2	......	31.25	38.84	29.91	1.21	3.97	55.01	1.83	8.07	......	5,560	10,008
			3	......	44.58	55.42	....	1.73	5.66	78.48	2.61	11.52	......	7,932	14,278
Sec. 28, T. 19 N., R. 6 E., Gale Creek mine (10 feet south of auxiliary slope, level 1 air course, No. 1 bed, 39½-inch cut).	9,908	B	1	5.49	36.40	50.05	8.06	.80	5.70	71.24	1.91	12.29	3.4	7,235	13,023
			2	......	38.51	52.96	8.53	.85	5.39	75.38	2.02	7.83	......	7,655	13,779
			3	......	42.1	57.90	....	.93	5.89	82.41	2.21	8.56	......	8,369	15,064
Same (gangway, level 2, 100 feet south of rock tunnel, No. 2 bed, 3-foot cut).	9,909	B	1	3.9	35.03	55.09	5.98	.96	5.63	74.97	1.95	10.51	2.4	7,636	13,745
			2	......	36.45	57.33	6.22	1.00	5.41	78.01	2.03	7.33	......	7,946	14,303
			3	......	38.87	61.13	....	1.07	5.77	83.18	2.16	7.82	......	8,473	15,251
Same (pillar between chutes 3 and 4, level 2 gangway north, Queen bed, 3¼-foot cut).	9,910	B	1	2.79	33.78	53.87	9.56	1.01	5.44	73.88	2.00	8.11	1.4	7,473	13,451
			2	......	34.75	55.42	9.83	1.04	5.28	76.00	2.06	5.79	......	7,687	13,837
			3	......	38.54	61.46	....	1.15	5.86	84.28	2.28	6.43	......	8,525	15,345
Wilkeson mine, sec. 34, T. 19 N., R. 6 E. (screenings re-washed).	9,898	B	1	6.6	23.32	56.51	13.57	.46	5.04	69.29	1.98	9.66	5.5	6,848	12,326
			2	......	24.97	60.60	14.53	.49	4.61	74.19	2.12	4.06	......	7,332	13,198
			3	......	29.21	70.79	....	.57	5.39	86.80	2.48	4.76	......	8,578	15,440
Same (600 feet west by 600 feet south of north quarter corner of sec. 34, 100 feet south of rock tunnel, No. 7 bed, 3½-foot cut).	9,899	B	1	5.94	23.17	61.13	9.76	.41	5.09	74.04	2.17	8.53	4.9	7,314	13,165
			2	......	24.63	64.99	10.38	.44	4.71	78.72	2.31	3.44	......	7,776	13,997
			3	......	27.48	72.52	....	.49	5.26	87.84	2.58	3.83	......	8,676	15,617

PIERCE COUNTY COALS.—TABLE OF CHEMICAL ANALYSES.—Concluded.

LOCALITY, BED, ETC.	SAMPLE			PROXIMATE				ULTIMATE					Air-drying loss	CALORIFIC VALUE	
	Laboratory No.	Kind	Condition	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen		Calories	British thermal units
Wilkeson, Wilkeson mine (Concluded).															
Same (3,000 feet north by 1,650 feet west of southeast corner of section 34, south end of east gangway, No. 3 bed, 68½-inch cut).	9,900	B	1	5.34	20.44	59.27	14.95	.45	4.52	69.79	1.91	8.38	4.3	6,833	12,299
			2	......	21.59	62.62	15.79	.48	4.15	73.73	2.02	3.83	......	7,218	12,992
			3	......	25.64	74.36	....	.57	4.93	87.55	2.40	4.55	......	8,571	15,426
Same (1,500 feet north by 1,200 feet west of the southeast corner of section 34, east water level, No. 2 bed, lower part, 95½ inches, 35-inch cut).	9,903	B	1	3.56	19.13	61.26	16.05	.49	4.41	70.52	1.94	6.59	2.8	6,843	12,317
			2	......	19.84	63.52	16.64	.51	4.16	73.12	2.01	3.56	......	7,096	12,773
			3	......	23.8	76.20	....	.61	4.99	87.71	2.41	4.28	......	8,512	15,332
Same (position and bed same as No. 9,903, upper bench, 17-inch cut).	9,904	B	1	3.06	18.48	54.95	23.51	.43	......	......	......	......	2.3	6,130	11,034
			2	......	19.06	56.69	24.25	.44	......	......	......	......	......	6,324	11,383
			3	......	25.16	74.84	....	.58	......	......	......	......	......	8,348	15,026
Same (50 feet up chute 19, southeast gangway, No. 3 bed, lower bench, 29-inch cut).	9,901	B	1	2.34	24.53	55.29	17.84	.48	......	......	......	......	1.2	6,809	12,256
			2	......	25.12	56.61	18.27	.49	......	......	......	......	......	6,972	12,550
			3	......	30.73	69.27	....	.60	......	......	......	......	......	8,530	15,354
Same (position and bed same as No. 9,901, upper bench, 78¾ inches, 42½-inch cut).	9,902	B	1	2.52	27.68	61.27	8.53	.42	5.23	76.94	2.05	6.83	1.6	7,717	13,890
			2	......	28.4	62.85	8.75	.43	5.07	78.93	2.10	4.72	......	7,917	14,251
			3	......	31.12	68.88	....	.47	5.56	86.50	2.30	5.17	......	8,676	15,617
Same (50 feet up chute 105 on southeast water level, No. 2 bed, 53½ inches, 46½-inch cut).	9,905	B	1	3.69	27.08	56.63	12.60	.45	5.08	72.54	2.19	7.14	2.8	7,210	12,978
			2	......	28.12	58.80	13.08	.47	4.85	75.32	2.27	4.01	......	7,486	13,475
			3	......	32.35	67.65	....	.54	5.58	86.66	2.61	4.61	......	8,613	15,503
2 miles southeast of: Snell mine (75 feet from entrance, Snell bed, 28 inches, 2-foot cut).	9,896	B	1	6.71	25.76	50.07	17.46	.78	......	......	......	......	5.4	6,424	11,563
			2	......	27.61	53.67	18.72	.84	......	......	......	......	......	6,886	12,395
			3	......	33.97	66.03	....	1.03	......	......	......	......	......	8,472	15,250

APPENDIX B—PIERCE COUNTY COAL PRODUCTION BY YEARS, 1885-1913, REPORTED BY STATE INSPECTORS OF COAL MINES.

NAME OF COMPANY	MINES	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	Total
Washington Improvement Company	Spiketon						1,000	1,100																							415,759
Willis Coal Company																	4,800														
Coast Coal Company																								2,770	10,168	42,812	78,961	84,781			
American Coal Company (1912)																													89,316	100,051	
Acme Coal Company	Spiketon								3,440	7,200	3,060																				13,700
Ouimette Mine	Spiketon									345	3,010	300	300																		3,955
Black Carbon Coal Company	Spiketon																			4,000					5,039						9,039
Gale Creek Company	South Willis																							19,263	8,880						200,660
Commonwealth Coal Company																										31,482	94,230				
South Willis Coal Company (1912)																													25,096	21,709	
Pacific Coal and Oil Company	Snell																					2,400	4,408	4,422							11,230
South Prairie Coal Company	Burnett	34,314	45,653	59,815		45,107	57,153	44,450	43,955	52,541	56,235	47,626	37,006	67,329	56,031	56,745	106,500	77,255	32,003	69,912	60,197	59,040									1,988,876
Pacific Coast Coal Company (1906)																							86,704	78,875	60,692	77,147	115,546	156,903	159,609	144,533	
Gale Creek Coal Company	Gale Creek																17,501	18,900	29,640	37,182	† 42,000										442,319
Tremont Coal & Coke Company																						26,640	19,200								
Gale Creek Coal & Coke Company																								44,739	56,319	29,689					
West Tacoma Coal Mines Company																											4,676	28,759			
Gale Creek Coal Mines Company																													37,829	49,245	
Tacoma Coal & Coke Company	Wilkeson	5,042	2,837	2,134		8,081	23,181	30,848	20,250																						2,279,933
Wilkeson Coal & Coke Company						6,738	4,720	31,489	82,132	77,546	86,972	85,688	88,480	86,613	96,838	166,148	116,622	125,028	106,896	55,399	63,724	72,512	67,700	139,272	117,425	72,663	118,732	107,420	132,960	127,843	
Brier Hill Coal Company	Wilkeson																							800	230						1,030
Carbon Hill Coal Company	Carbonado	135,926	120,965	June 30 145,316	Oct. to Sept. 195,387		179,457	161,041	203,980	267,545	266,111	303,087	297,000	310,488	335,000	287,952	341,633	323,395	169,733	280,123	233,705	173,226	191,939	246,718	251,721	239,612	277,723	319,213	283,422	293,542	6,834,960
Northwestern Improvement Company	Melmont																		24,000	83,100	92,944	95,595	61,543	37,431	71,385	80,292	63,871	76,734	61,088	64,072	812,055
Western American Company	Fairfax, Sec. 26															250	8,549	30,513	32,117	33,600	22,000	26,111									271,675
Fairfax Mine																							21,964								
Tacoma Smelting Company																								15,474	3,694	27,307	28,138	21,958			
Fairfax Mine, Inc.	Fairfax, Sec. 34																												* 2,250	30,972	33,222
Washington Cooperative Mining Company, and Montezuma Mining Company	Montezuma																		6,702	11,970											80,531
Evans Creek Coal & Coke Company																							5,333	22,775	16,737	13,625	3,084			305	
Western Steel Corporation	Ashford																									655					655
Totals		175,282	169,455	207,265		255,313	265,511	268,928	353,757	405,177	415,388	436,701	422,786	464,430	487,869	461,095	595,605	575,091	401,091	575,286	514,570	455,524	458,791	612,539	602,290	615,284	784,961	795,768	791,570	832,272	Grand tot'l 13,399,599

† Includes South Willis. * Based on 1,487 tons coke.

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Water Supply Paper No. 292: Surface Water Supply of the United States, 1910. Part XII, North Pacific Coast.

Water Supply Paper No. 312, 1912: Surface Water Supply of the North Pacific Coast Basins.

Water Supply Paper No. 332: In preparation.

Water Supply Paper No. 346: Profile surveys in the basin of Clark Fork of Columbia River, Montana-Idaho-Washington.

Water Supply Paper No. 366: Profile surveys of Snoqualmie, Sultan, and Skykomish rivers, Washington.

Water Supply Paper No. 368: Profile surveys in Wenatchee River basin, Washington.

Water Supply Paper No. 369: Profile surveys of Cle Elum, Naches, and Tieton rivers, Washington.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE, BUREAU OF SOILS, IN CO-OPERATION WITH THE WASHINGTON GEOLOGICAL SURVEY.

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Reconnoissance Soil Survey of the Eastern Part of the Puget Sound Basin.

Reconnoissance Soil Survey of the Western and Southern Parts of the Puget Sound Basin.

Reconnoissance Soil Survey of Southwestern Washington.

Reconnoissance Soil Survey of the Quincy Area.

Reconnoissance Soil Survey of Stevens County.

Reconnoissance Soil Survey of Franklin County. In preparation.

LEGEND

Eocene — Ep — Puget Formation	Post Eocene — Na — Pyroxene-Andesite	Pleistocene — P — Gravels

Mine Gangways
◆ Prospects

GEOLOGICAL MAP
OF
PIERCE COUNTY COAL FIELD

SCALE 1 INCH = 1 MILE
SEPTEMBER 1913

MINE WORKINGS AND STRUCTURE MAP

WILKESON-CARBONADO DISTRICT

PIERCE COUNTY COAL FIELD

SCALE 1 INCH—1,000 FEET

SEPTEMBER 1913