OPERATIONS OF THE NORTHWESTERN IMPROVEMENT COMPANY
IN THE ROSLYN-CLE ELUM COAL FIELD

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INTRODUCTION

The operations of the Northwestern Improvement Company are situated in the limited Roslyn-Cle Elum coal field, which is in northwestern Kittitas County, Washington. The field, five miles wide and seven miles long, is folded into a series of anticlines and synclines, their axes pitching 7°. The dip of the flanks ranges from a minimum of 8° in the northern part of the field to a maximum of 54° in the southern part. The coal seams at the upper or north end of the field outcrop into an average of 50 ft of glacial debris, and are higher above sea level than the coal in the lower half of the field, which is under as much as 1,600 ft of cover at the basin of the synclines.

Low-dip and basin workings are similar to the level-mining done in other sections of the country. However, the high dips reached in the lower half of the field require methods that are distinctly new in slope operations under mechanized mining. In the low coal seams in this field the tonnage output per man at the face has proved inversely proportional to the dip. Both the number of board feet of lumber used per ton of coal extracted and the amount of rock brushing on haulageways are directly proportional to the inclination.

Owing to the thinness of the seams, to the varying dips arising from the folding of the coal-bearing substratum, and to the physical makeup of the coal-bearing layers, revolutionary mining machinery and mining systems have been developed. One remarkable designing and construction job done by company men was the installing of a central coal-cleaning plant for all mines of the Northwestern Improvement Company. The washer, with a capacity of 200 tons per hour, was designed after much preliminary study and analysis. Because of the experience of its personnel in coal cleaning, and particularly because of the understanding of this particular problem gained through the preliminary studies, the company decided to design and build the plant itself, rather than give the contract to some outside firm.

The Northwestern Improvement Company is one of the leaders in coal mining, coal preparation, and safety experimentation in the coal fields of the northwestern United States.

OBJECT OF THESIS

For the use of those interested in recent coal-mining practices in this state, data are here presented on the mine-mechanization and cleaning-plant programs developed by the Northwestern Improvement Company.

The writer has attempted to explain the irregularities of the coal seams, on which these practices are based. All opinions throughout this report are strictly his own; the geological assumptions are dependent only upon practical data.

FIELD AND LABORATORY WORK

The field work for this thesis was begun in the summer of 1931, when the writer first worked for the Northwestern Improvement Company. The underground geology and the mining methods were observed during several summers of work. Two traverses of the western boundary of the coal field were made in the spring of 1940.

Samples of the sandstone boulders appearing in the Roslyn seam and samples of the hanging wall near the boulders were examined microscopically. Many of the surface pictures were taken by the writer, and on several occasions he accompanied the commercial photographer and the safety engineer when the mine pictures were being taken.

EARLIER PUBLICATIONS

From the years 1893 to 1914 two United States Geological Surveys covered the local sedimentary formations in the Roslyn and Manastash coal areas in their regional geological surveys. Two state geological surveys during that time gave detailed geological treatment of the coal-bearing formations. In bulletin No. 9 of the 1914 State Geological Survey, a complete description of the underground geology and mine workings of the Roslyn-Cle Elum coal field is given by Joseph Daniels, professor of mining engineering and metallurgy at the University of Washington.

Company officials, United States Bureau of Mines' officials, geologists, and prominent consulting engineers have in recent years published various discussions of the geological and operating phases of the Northwestern Improvement Company. Their works have been the source of much of the information included in this thesis.

ACKNOWLEDGMENTS

The compilation of a report of this kind would be impossible without the assistance and suggestions of mine officials and faculty members. D. R. Swem, manager of coal operations, Thomas Murphy, general superintendent of mines, Earl McMillan, chief mining engineer, and Harry Boyle, chief resident engineer, of the Northwestern Improvement Company, have extended many greatly appreciated courtesies and have supplied much of the specific information contained in the report. Valuable assistance was given by Frank Badda, safety engineer, John Lewis, Mine 5 foreman, and Claude Murphy, unit foreman of the company. Edward Richards, general superintendent of the Roslyn Cascade Coal Company, contributed much of the information on mining geology.

The writer is indebted to Professor Densmore of the

University of Washington, under whose supervision and department the work was prepared, and to Dean Milnor Roberts of the College of Mines, who generously gave recommendations for the assembling of the data for the final report. Professor Barksdale of the geology department gave valuable recommendations upon mining geology, and Miss A. V. Hall of the English department offered constructive criticisms of the paper.

GEOLOGY

GEOGRAPHY

Location and Boundaries

The Roslyn-Cle Elum coal field is located in northern Kittitas County, the most centrally located county in the State of Washington. The county seat, Ellensburg, is 115 miles east of Seattle and Tacoma, 205 miles west of Spokane, and 35 miles north of Yakima. The county is bounded on the east by the Columbia River, on the south by foothills, and on the west and north by ranges of the Cascade Mountains.

The Roslyn-Cle Elum coal area lies just at the eastern foothills of the Cascade Mountains, under the western edge of the Yakima basalts, at elevations ranging from 2,000 to 3,700 feet, the highest point on the coal-outcrop line. The coal field extends diagonally across township 20 north, range 15 east, from the town of Cle Elum to the lower end of Lake Cle Elum. Located along the Yakima and Cle Elum River valleys, it includes at the western end of the field parts of sections 1, 2, 11, 12, and 13 of township 20 north, range 14 east and sections 35 and 36 of township 21 north, range 14 east, and at the eastern end of the field takes in a few sections in the west-central portion of township 20 north, range 16 east.

Settlements

The towns of Roslyn and Cle Elum owe their beginnings to the Northwestern Improvement Company, a subsidiary of the Northern Pacific Railway Company.

Roslyn, Washington, is a coal-mining town situated in the eastern foothills of the Cascade Mountains in Kittitas County at an elevation of 2240 feet. It has a total population of about 2500 people. Although off the main lines of travel, it is easily accessible by railway and by highway. Both connect it with Cle Elum, a town with the same economic base, about three miles to the southeast.

In 1884 the Northwestern Improvement Company sent two men, G. W. Driver and Pete Sherry, into this district to check rumors acclaiming the presence of coal. These men located coal in the region immediately northwest of the present site of the town. In 1885, H. C. Walters also verified the findings. A year later, an engineer was selected to plot the town of Roslyn, and in the very same year the Northern Pacific Railway began building its line from Cle Elum to Roslyn. The first coal was mined from this area in 1886.

Unfortunately, in order to locate near the coal mines, the town has been built in a narrow valley - hardly desirable for residence or business - surrounded on either side with hills. Nevertheless, the residential sections of the town have expanded even into the less undesirable portions of this land. At the present time a large part of the residential sections is built on hills, the business center being below, within the valley.

The town is primarily a service community. The coal mined in this region is distributed, on order, through dealers located in all parts of the state, and also to the Northern Pacific Railroad's coast fueling bunkers. Other than in the distribution of coal, Roslyn exerts no wide influence. The small town of Ronald, with a population of 1,000, practically a suburb of Roslyn, is a mile and a half to the northwest.

Cle Elum came into existence with the construction of the Northern Pacific railway, on the main line of which road it is situated, in 1886-87. Its growth has been steady, not the result of a boom; and the business and commercial interests have kept pace with the requirements of the city and the tributary districts. It has now reached a population of 3,000.

Cle Elum's chief asset is the coal-mining industry, with lumbering and agriculture as secondary interests. Many large ranches are in the near vicinity, and logging operations are carried on extensively within a radius of twenty-five miles. The city has improved a great deal in the last few years, owing to the tourist trade from the Snoqualmie Pass highway. South Cle Elum, half a mile east of Cle Elum on the Chicago, Milwaukee, and St. Paul railroad line, is a suburb with a population of 600.

Early History

Although coal prospects had been discovered previously, not until May, 1886, did the Northern Pacific Railroad Company send its first party to develop the ground. The men were H. E. Graham, Harry Cottle, Thomas Fleming, Archie Patrick, William Thompson, Archie Anderson, and William Anderson; they were supplied with all the improved equipment of a diamond-drilling outfit. The first stop was made at Masterson's ranch, four miles east of Cle Elum, where a hole was sunk. From there the drill was moved to section 21, north of Cle Elum, where the second sinking was done. Thence the work continued until June, when the present extensive mines of the Northern Pacific Coal company were discovered and located.

The surface croppings were first discovered near the mouth of the tunnel on side No. 2, and permanent work was begun on August 12, 1886, by a force of 18 men under the supervision of James Anderson. The development work continued until the advent of the railroad on December 14, when coal was first taken out for traffic purposes. From that day on, the force of miners, drivers, etc., was steadily increased. New works were laid out and were opened up until the spring of 1887, when the population of the camp had attained the number of five hundred people, chiefly laborers, and substantial employment was afforded many others in different lines of work.

A few months before the discovery of the coal beds, a party of prospectors of the Union Pacific Railroad, with Bailey Willis as the leader, explored this section but failed to find any coal.

Travel Routes

At the present time, the six-mile Roslyn branch of the Northern Pacific Railroad extends a little beyond the Roslyn Cascade Coal Company's property above Ronald, Washington. A paved road leads from Cle Elum to Ronald, a distance of about five and one half miles; a well graded, graveled road leads on to Lake Cle Elum.

A mile south of the Roslyn city limits is a wide bituminous-surfaced cut-off road that connects the Roslyn-Cle Elum highway with that to Snoqualmie Pass. The undeveloped areas of the coal field are well traversed by roads built for fire fighting, fishing, and hunting.

Climate and Vegetation

The climate of northern Kittitas county is semi-arid. The greater portion of the precipitation comes in late fall, winter, and spring, and thus is favorable storage for irrigated crops. Precipitation during the winter months is generally in the form of snow. This region has one of the finest climates to be found in the United States. With the exception of a few isolated points on the Columbia river, it has more days of sunshine than any other place in the Northwest. A yearly average of more than 200 days are marked as clear, and of the remaining days not more than 80 are poor. The thermometer seldom drops below zero in the winter months, and the summers are long and cool; not so cool, however, as to interfere with the growing of crops. The prevailing wind is from the northwest. A large percentage of the days are very calm, with little or no wind during the winter months. Warm summer days are invariably cooled during the afternoons and evenings by air currents flowing down into the valleys from the mountains. Crop damage by hail storms or violent winds is unknown.

The natural scenery of the Cle Elum country is unexcelled. Innumerable small lakes and rivers are found throughout this region, and owing to the semi-arid climate this is the center of one of the finest timber belts in the Northwest. The soil will give excellent yields of timothy hay, fruit--especially winter varieties--potatoes, oats, wheat, and other cereal crops. Much of this land requires water, and this is furnished by the Hi-Line Canal. Starting at the dam at Lake Easton, this canal runs through Badger Pocket toward Vantage on the Columbia River, and supplies water to the whole valley. Owing to the Cascade-range barrier the eastern portion of the state receives less rainfall than the western.

REGIONAL GEOLOGY

Stratigraphy

a. Historical Table

FORMATIONS	THICKNESS (feet)	DESCRIPTION
PLEISTOCENE GRAVELS	10-600	Some red-stained till and some stratified clay, gravel, and boulder glacial and river deposits.
YAKIMA BASALT	100-5,000	Basaltic extrusive flows that are the products of fissure eruptions, not of volcanoes.
	EPOCH OF EROSION AND DIASTROPHISM	
ROSLYN	2,000-3,500	Massive yellowish-brown sandstone and subordinate quantities of clay shales and carbonaceous shales including coal seams which accumulated on broad valley flood plains and in lakes of temporary duration.
TEANAWAY BASALT	100-4,000	Basaltic lava flows and intercalated tuffs, possibly in part the equivalent of the Metchosin volcanics of Western Washington
	EPOCH OF DIASTROPHISM AND EROSION	

(Continued)

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FORMATIONS	THICKNESS	DESCRIPTION
SWAUK SANDSTONE	1,000-5,000	Massive arkosic quartzose light and dark brownish-gray sandstone, stratified conglomerate and interstratified grayish-brown carbonaceous shales which accumulated upon broad valley floors which were differentially being warped downward. The base of the formation rests on older igneous and metamorphic rocks and may be of very late Cretaceous age.
EASTON SCHIST		Quartz-mica schists, amphibolites, and epidote schists.

b. Pre-Tertiary Easton Schist

The pre-Tertiary formations exposed in the Cascade mountains of central Washington are described in the geologic folios of the Mount Stuart and Snoqualmie quadrangles,[7, 8,] where the Easton schists, black slates, and limestone of the Peshastin formation and the greenstones and breccias of the Hawkins formation appear flanked on their margins by Tertiary lava and continental sandstones. Associated with these older rocks are intrusive masses of gabbro and peridotite, as well as intrusive batholiths of granodiorite. Rocks of the Cretaceous age have not been recognized, unless the lower portion of the sandstones of the swauk formations extend down into the very late Cretaceous.

The Easton schists, consisting of quartz-mica schists, amphibolites, and epidote schists, are well-exposed on either side of the Yakima river, where they lie unconformably beneath Eocene sediments and late Tertiary lavas.

c. Eocene Series of Eastern Washington

The Eocene is represented in eastern Washington by six formations, two of which are composed mainly of volcanic material and four of continental sediments.[9] These formations may be arranged in the following stratigraphic descending sequence:

Manastash formation	Naches formation
Roslyn formation	Kachess rhyolite
Teanaway Basalt	Swauk formation

The Swauk and Naches formations, together with the Kachess rhyolite, are probably in part contemporaneous, but have accumulated in separate basins which, if ever connected, were only for a short duration of time. The Kachess rhyolite consists of numerous flows intercalated within the Naches formation. The Teanaway basalt rests unconformably upon the Swauk formation, and the Roslyn upon the Teanaway basalt, with only a very slight unconformity. The Manastash formation occurs in a separate basin, and lithologically closely resembles the Roslyn. Faunally, it is closely related to the Clarno formation of central Oregon, whose floral characteristics possess a definite Eocene association. The Swauk and Naches formations rest with marked unconformity upon the older metamorphic and igneous rocks.

Diastrophism followed by erosion is evidenced by the gentle folding, uplift, and partial erosion of the Swauk formation prior to the outpouring of the Teanaway basalt. Possibly, portions of the Naches formation may have accumulated during this diastrophic and erosional interval, as well as some of the flows of the Kachess rhyolite. The shaly portions of the same formation in places contain well-preserved fossil leaves. The biology of the flora is imperfectly known, but the floral assemblage in the Swauk has its closest relationship to the early Eocene and even to a small extent with the flora of the uppermost part of the Cretaceous. Such fossil leaves as have been collected from sandstones intercalated within the basaltic flows of the Teanaway volcanics, show a close relationship to the fossil floras of the Carbonado formation.[8] The flora and fossil fish of the Roslyn formation are representative of the middle Eocene, although a majority of the species are new. Such flora as have been collected from the Manastash formation are entirely different from those of both the Swauk and the Roslyn formations, but are closely allied to those of the Clarno formation in eastern Oregon. The sediments of the Manastash formation may have accumulated during the latest part of the Eocene, and have continued into the earliest Oligocene.

Early in the Eocene epoch, the site of the present Cascade mountains in central Washington possessed a topography of low and irregular relief and was not greatly elevated above the level of the sea. The low lands represented early Eocene valleys, through which streams were flowing westerly across the coastal plain on their way to the ocean. During the early Eocene the shoreline appears to have occupied some unknown position west of the present coast line, since deposits of the earliest Eocene, equivalent to those of the Martinez formation in California, occur at no place in western Oregon or Washington.[9] The differential downwarping of the western portion of Washington, including the area of the present Cascade mountains, was probably responsible for the widening and deepening of the river valleys and for their partial and temporary conversion into fresh-water lakes. The sediments which accumulated in the lake basins appear to have trespassed beyond the shores of the lakes and on to the floors of the surrounding valleys. The thick accumulation of sandstone and shale farther west in the present site of the western foothills of the Cascade mountains, described as part of the Puget group, probably represents materials carried westerly by the same rivers which passed through the valleys in part occupied by the fresh-water lakes, in which a part of the sediments of the Swauk formation accumulated.

The Teanaway basalts which rest unconformably upon the eroded and folded sediments of the Swauk formations are probably equivalent in time to similar lavas of the Metchosin volcanics, so widely distributed throughout western Washington and the southern end of Vancouver Island. New basins developed after the outpouring of the Teanaway basalts in eastern Washington and the Metchosin volcanics in the western part of the state. These permitted the temporary existence of lakes within portions of the broad valley floors, and led to accumulation of the Roslyn and Manastash formations east of the Cascades as continental deposits and to the Crescent and Cowlitz formations in the marine embayments of western Washington.

d. The Two Coal-Bearing Formations

1. Roslyn

The Roslyn formation is best exposed on the northern side of Yakima valley, between Swauk creek and Lake Cle Elum on the eastern side of the Cascade mountains. It overlies the Teanaway basalts without any marked unconformity, although probably the erosional interval was sufficient to allow surface weathering of portions of the upper flows of the basalt. However, no locality appears to have interbedded sands and tuffs, or individual lava flows. After the outpouring of the Teanaway lavas, crustal warping allowed the development of a basin of deposition for the accumulation of the basal sediments of the Roslyn formation. The largest area of these lies in the lower drainage basin of Teanaway river, and continues southward into the valley of the Yakima river near Cle Elum and Roslyn. The strata have been warped into gentle folds whose axes follow the course of the Yakima river between the towns of Teanaway and Roslyn. The inclination of the beds varies from 5° to 54°, and the maximum thickness now exposed approximates 3,500 feet.

Lithologically, the Roslyn formation consists for the most part of massive yellowish-brown sandstone together with coarse sandy shale and fine-grained brownish-gray shales. Thin lenses of conglomerate occur at some localities, but are uncommon as a constituent part of the formation. The sandstones are composed prevailingly of a quartz arkose with fair stratification. The fact that the most productive coal beds are in the upper 1,200 feet of the formation, suggests that deposition went on under steadily shallowing conditions.

Collections of fossil plants were made many years ago by George Otis Smith, and later were studied by Knowlton.[7]

Thirteen genera were recognized, but not a single species is common to the flora of the Swauk formation. The Roslyn beds are the younger, and are considered as belonging to the upper half of the Eocene.

2. Manastash

The Manastash formation occurs near the headwaters of Manastash and Teneum creeks on the south side of the Yakima valley, about 20 miles west of the city of Ellensburg. The formation is composed of massive quartzose sandstone with interstratified layers of fine-grained brownish-gray shale containing seams of impure coal. It rests with a basal conglomerate unconformably upon the Easton schists. Lenses of conglomerate containing pebbles of white quartz are common within the sandstones. In thickness, the formation varies from 200 to 300 feet, and it is overlain unconformably by the Yakima basalts; it is penetrated by diabase dikes occupying conduits which were the feeders to the overlying lavas.

The paleobotany was studied by Knowlton, and no species were recognized as occurring in the Roslyn or Swauk formations.[7] However, two species of oak are present in the flora of the Clarno formation of the John Day Basin in eastern Oregon, and other species are said to occur in the sediments at Corral Hollow on the south side of Mount Diablo in California.[9] The faunal relationships led Knowlton to the belief that the Manastash formation is of upper Eocene age and may be equivalent to the upper Roslyn as well as very late Eocene and possible early Oligocene.

e. Mid-Miocene Yakima Basalt

A decided unconformity between the Roslyn formation and the overlying Yakima basalt indicates a long period of erosion between the uplift and folding of the Eocene rocks and the extrusion of the lava flows. The first fingerlings of this basalt is seen a few miles southeast of Cle Elum at Teanaway. A little farther in that direction from Cle Elum, the Roslyn formation passes under Table Mountain, a ridge of hard Yakima basalt.

A very complete discussion of this huge Columbia River lava plateau, prepared by the geology department of the University of Washington, is contained on the following pages.

> The Columbia River lavas are a series of extursive flows which form one of the most remarkable examples of volcanic activity in the world. They are of wide extent, covering most of eastern Washington, southern Idaho, and eastern Oregon. Mainly of basaltic composition, they are the products of fissure eruptions, not of volcanoes.
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> The fissures or cracks which formed the feeding channels for these surface flows are commonly about 50 feet wide and may attain a length of several miles. They were presumably the result of tensional stresses and were more or less localized. Filled with solidified lava, they now appear as dikes where erosion has worn away the superincumbent flows. They are common in some of the more mountainous portions of the region such as the Blue Mountains and in some of the steeply-incised river canyons, as the Snake River Canyon along the Oregon-Washington-Idaho boundary.
>
> The formation of these extensive lava flows must have been a spectacular geological event when hot lava, with a temperature around 1,000° C., welled upward through

the fissures and flowed out over the surface, filling valleys and spreading over plains. Flow after flow was poured out, one on top of the other, so that the volume of rock formed may have totaled 150,000 cubic miles. In some sections there is virtually no intervening material, the later flows advancing upon the chilled surfaces of older ones. At other places gravels, sands, and clays are intercalated with the extrusive lava sheets, thus indicating the lapse of time between periods of volcanic activity.

The topography of the old land surface covered with these floods of basaltic lava ranged from moderate relief in the western portion of the volcanic field to considerable relief along the Idaho border. Here whole mountain ranges with peaks rising over a thousand feet above their valleys were buried completely. In eastern Washington the isolated summits of a few of the higher of these old mountains stand like islands in a sea of lava. Steptoe Butte is such a classic example of this type that the term "steptoe" has this meaning in geological literature.

The major portion of the Columbia River lavas occupies a depression some 400 miles long and 100 miles wide, extending through central Washington and Oregon. To the east the lavas penetrated the old valleys which drained the central mountain mass of Idaho. In the extreme northeastern part of Oregon now occupied by the Wallawa Mountains later uplift accompanied by faulting has hastened erosion of the lavas so that many square miles of the older rocks are exposed.

Through the entire volcanic field the basalt flows form striking features of the landscape. Where a succession of flows has been incised by a stream the canyon walls are commonly in terrace form. One or two flows may form the cap rock or rim rock, producing a prominent remnant of erosion, with the hard lava protecting the softer rocks beneath.

Two characteristics of the flows are responsible for the common landscape feature of cliffs and terraces. One of these is called columnar structure or columnar jointing, so named on account of the columnlike forms produced by cracking, due to shrinkage on consolidation of the lava. Naturally these columns will stand at right angles to the cooling surfaces. The other characteristic is the porous or vesicular nature of the upper portion of most of the flows. This is formed by the collection of gas bubbles which have risen through the molten lava. It is this distinct difference in appearance of the vesicular upper portions to the denser lower portions of the flows (commonly showing columnar structure) that enables one to determine the number of individual flows in a series. As might be expected, the porous lava allows ready access to ground water, so that springs may occur along the vesicular outcrops. This will also promote weathering, and the softer, more altered porous portions will be eroded away easily and therefore will form the gentle slopes, while the harder, denser rock will form the cliffs. If col umnar jointing is present very steep cliffs will result, since the columns will break off one by one as erosion proceeds, leaving vertical walls.

When lava sheets are horizontal the height of the terrace wall varies with the thickness of the flow. Along the Oregon-Idaho border individual flows are commonly 100 feet or more thick; in the Mount Stuart and Ellensburg region 20 to 50-foot flows prevail, while in the Wenatchee-Chelan district the flows are 75 feet thick.

The name Columbia lava was given to the volcanic rocks of this field in 1893 by I. C. Russell of the United States Geological Survey. In 1901 he changed the name to Columbia River lavas to avoid confusion with Columbia formation of the Atlantic coast. Under these names he included all the lava flows ranging in age from the early Tertiary Eocene up through the Pliocene. In 1902 Merriam defined the lavas as the series between the John Day and Mascall formations, thus limiting them to upper Miocene. About the same time George Otis Smith grouped the Miocene lavas of the Ellensburg Folio as Yakima basalt. More recently the trend is again to consider the Columbia River lavas as a general term and to subdivide them into local groups without giving them formational significance.

In appearance the basaltic rock of the Columbia River lavas is dark brown on weathered surfaces and very dark gray to black on freshly broken surfaces. Most of the flows are very fine-grained or even aphanitic in texture, with none of the constituent minerals visible. A few have a coarser grained texture.

In thin section under the microscope the Columbia River lavas are seen to be, in the main, of basaltic composition. Their usual mineral assemblage is plagioclase feldspar (labradorite), augite, with or without olivine, some magnetite, and varying amounts of a residuum of glass. Intersertal textures are common, and in some places alteration material is present.

f. Pleistocene Gravels

Folding, uplift, and erosion reduced these earlier formations to the Pliocene peneplain.[6] Further uplift, warping, and erosion produced the "Cascade Plateau", and caused the raising of ridges in the lava plains transverse to the general trend of the Cascade Mountains.[6] These two uplifts closed the Tertiary period, and the Quaternary period since has seen active erosion of the "Cascade Plateau" into its present form.

Early in this period climatic changes filled the higher Wenatchee Mountain valleys with large glaciers. Three valleys that are now occupied by lakes Keechelus, Kachess, and Cle Elum were glacially gouged, leaving heavy terminal moraine barriers about the position of lower ends of the present lakes.

Streams carrying glacial detritus deposited the deep gravel fillings in the valley bottoms. The Yakima River and many of its tributaries are re-excavating their valleys in the glacial gravels forming many gravel terraces.

Because of stream transportation, much of the Pleistocene material is roughly stratified, although in some areas red-stained glacial till is seen. The lithology of the 600-ft glacial formation at Cle Elum as recorded in diamond drill-hole records is as follows: 30 to 50 feet of heavy boulders at the bedrock, 400 feet of fine glacial silt and blue clay, and a capping of 100 to 150 feet of boulders. While drilling, if big boulders were met, nitro-glycerine charges shattered the rock masses. Often before starting a hole, drillers would sink shafts through the first boulder formation.

The blue clay acts as a water seal and so mining may be carried up near the river beds. The Cle Elum River seals itself off very quickly because the amount of sediment it is carrying in suspension. This has been ovserved clearly in the South Cle Elum water wells that were put down near the river. The water seepage into the wells did not come from the river as planned, but rather from the gravels nearby.

g. Late Topography and Drainage

During the earlier part of the Pliocene, or the later part of the Miocene, the Miocene and underlying series were uplifted and gently folded. The Yakima River and its tributaries, after planing off the surface, flowed over it with little regard to rock structure, in a well developed meandering course.

As a closing event of the Tertiary period, the Cascade Mountains were formed by uplift, and the ensuing mass has been called the Cascade Plateau. The uplift was accompanied by a gentle folding or warning, following in general the lines of previous folding, which caused a number of ridges in the lava plains to be raised transverse to the general trend of the Cascade Mountains and the course of the Yakima River. The warping took place slowly, and so the Yakima and its tributaries were able to maintain their courses across the ridges, and in the igneous rocks to entrench themselves in deep canyons. In rocks less resistant, the antecedent streams cut out wide valleys.

The topography of northern Kittitas county is therefore wide open valleys in the Roslyn-Cle Elum sedimentary area, and gorged canyons east of Bristol, where the basalts and andesites limited the meandering of the Yakima river. Cle Elum and Teanaway Rivers, and Big and Little Creeks, are all captured by the Yakima above Bristol or in the upper part of the county.

Structure

The field structure is that of an unsymmetrical syncline, pitching 6° to the southeast. The long synclinal flank on the eastern edge of the field dips from a minimum of 8° at the northern point of the coal area to a maximum of 54° at the lower side of the Roslyn area of the field.

The underground structure has conformed in the past 26 years to the hypothetical structure sections interpreted by the Washington State Geological Survey of 1914.[6] The synclinal basin was not reached as quickly, nor was the basin quite as abrupt as was previously thought, but the dip of the opposite flank of the syncline conformed exactly.

Recent developments show that the glacial-covered anticline is a saddle-and-trough structure. The anticlinal workings of Mine 3 and of Mine 9 pitch toward each other into a saddle. Mine 9 is situated upon a pronounced dome.

The western flank dips of the anticline have been prospected by entry workings of the above mines. Undoubtedly local irregularities will be found in the folded structure, but the prospected flank of the anticline will extend down to a basin, with the coal seams probably rising to an outcrop in the glacial material at the western edge of the field. The composite structure of the field (Plate I) will then be two synclines bordering a central irregular anticline.

Faults

Only within recent years have many true faults been found in the Roslyn field. The majority have occurred in the middle of the coal area, where the dip of the strata begins sharply to increase. The first was found in the Mine 5 flank on the west of the syncline, and has been fully discussed by Joseph Daniels in Bulletin 9 of the State Geological Survey. The Roslyn seam and adjacent strata were sharply folded eastward into a near recumbent fold before fracturing into an overthrust fault with a displacement of 16 feet.

On the opposite or eastern flank of the syncline, 1500 ft northward of the above-mentioned fault, is the fault of Mine 9. It is overthrust, and has a displacement of 28 ft and a movement eastward. Faults of this type help to prove that the pressure which produced the folding of the Roslyn sedimentary formations came from the west and was perpendicular to Teanaway Ridge.

At varying degrees from the north-south strike lines of the above faults, occur two other overthrust faults. Both are on the west flank of the covered anticline; one is in each of Mines 5 and 9 again, and they are of 4-ft and 28-ft displacement, respectively.

Sandstone Inclusions in the Roslyn Seam

The sandstone inclusions that appear in the Roslyn seam extend the entire length of the field. They often appear grouped in nests and invariably they occur near the axis of the syncline. Few of them are found in the upper part of the eastern synclinal flank, and none has been met as yet on the little developed western flank of the anticline.

These rock inclusions are to this field what faults are to the western coal fields of the state. Coal tonnage lost and rock tunnels required by their presence are enumerated as follows:

Number of sandstone inclusions encountered: 27

Largest boulder: 1200 ft by 400 ft by 12 ft
(coal seam is 4-1/2 ft)

Tonnage replaced: 426,666 tons of coal

Rock tunnels required by their presence

480 ft of main slope

200 ft of incline

1040 ft of entry

The sandstone irregularities are bullet-shaped, with well-rounded blunt ends and tapering tails. The orientation of the inclusions is very regular, considering the large size of the area in which they are contained: the blunt ends point generally, N 45° W.

In some cases these boulders are surrounded by bottom coal, as well as by top coal, with the composite thickness of the coal approximately the same as the average of the seam. The coal immediately surrounding them contains a higher carbon content, with consequent greater degrees of hardness. The change is doubtless due to accumulations in the coal seam during the folding processes. Because the sandstones are nearly all on the line of the synclinal axis, the intensity of folding was greatest there. Every foot of bituminous coal preserved here must have meant close to thirty-five feet of organic sediment.

During the investigation of Mine 9 by the writer on this problem, coarser shales and sandstones were observed to have surrounded the Roslyn seam than at other mines observed. The coal seam had thinned to 4-1/4 ft, while the average of the sea is 4-1/4 ft. Little fossil accumulation and preservation was noted.

A logical conclusion is that if the areas containing these coarse sandstone irregularities contained the features mentioned immediately above they would be, not in backwash and protected areas, but rather in stream-channel areas where

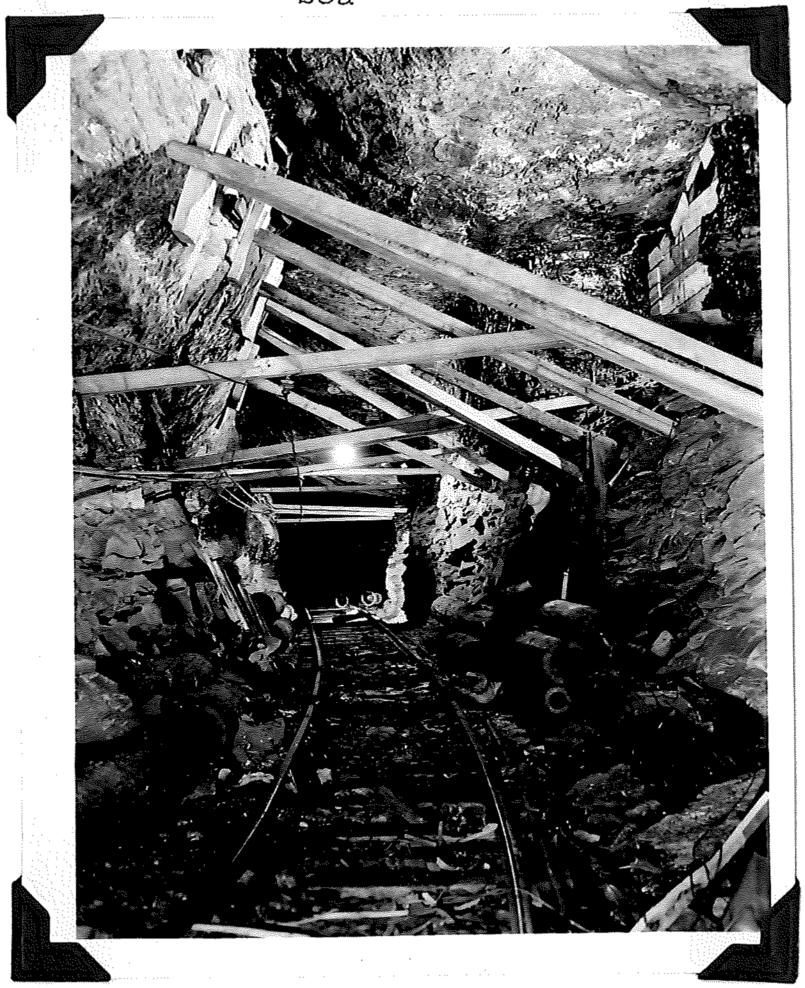


Plate I. Sandstone inclusion in the Roslyn seam. Inclusion shown is 171 ft long, and its height tapers from 12 ft to 4 ft. There is 2 to 3 ft of top coal and 1 to 2 ft of bottom coal.

Plate II. Roslyn conveyor springboard. It is used on dips over 20° to aid the conveyor in thrusting the pans up t he hill.

the coarser sediments would be first dropped out. Such precipitation must have occurred, for these accumulations evidently did settle out at the same time that the organic background of the coal was building up.

Samples were taken from some newly exposed lenses, and microscopic examination has shown the sandstone coarse throughout, with little differentiation. Sharply defined stratification is seen at the surface, and shelly-spheroidal disintegration occurs, probably from pressure release after the inclusions have been exposed.

Supporting evidence for any definite statement of origin of these sandstone inclusions is weak, and will probably remain so as long as there are different and varying theories of coal formation, as well as different types of coals. Samples of the Roslyn seam irregularities, examined by the writer in Mine 9, show cementing materials the same as those common to the strata directly above the Roslyn coal seam in the particular mine area examined. Almost all underground waters carry mineral solutions gathered in their coursing, and as no foreign materials appear in the cements the spring-percolation-origin theory of these sandstone masses is not substantiated. Lack of differentiation and of fine material also supply some argument against spring accumulations.

The explanation given of irregularities, termed "horses", occurring in Illinois and Kansas coal beds, cannot well be applied here. In those fields the coal-bearing strata were folded before enough cover and aging had hardened the sediments. When the measures were folded, the coal beds cracked, and the underlying silts and clays flowed into the openings. Widened wedge bases acting as sandstone feeders have not been observed in the Roslyn mines.

The writer concludes that most likely the origin of the sandstone bodies is stream deposition. The shapes of the lenses portray a modified delta structure: blunt ends where the greatest mass of material accumulated, with tail gradation as though a former stream mouth was being choked up by backing accumulations. The formation might be attributed to sand bars, or perhaps to simple infilling of depressions of the lowland bottom.

COAL

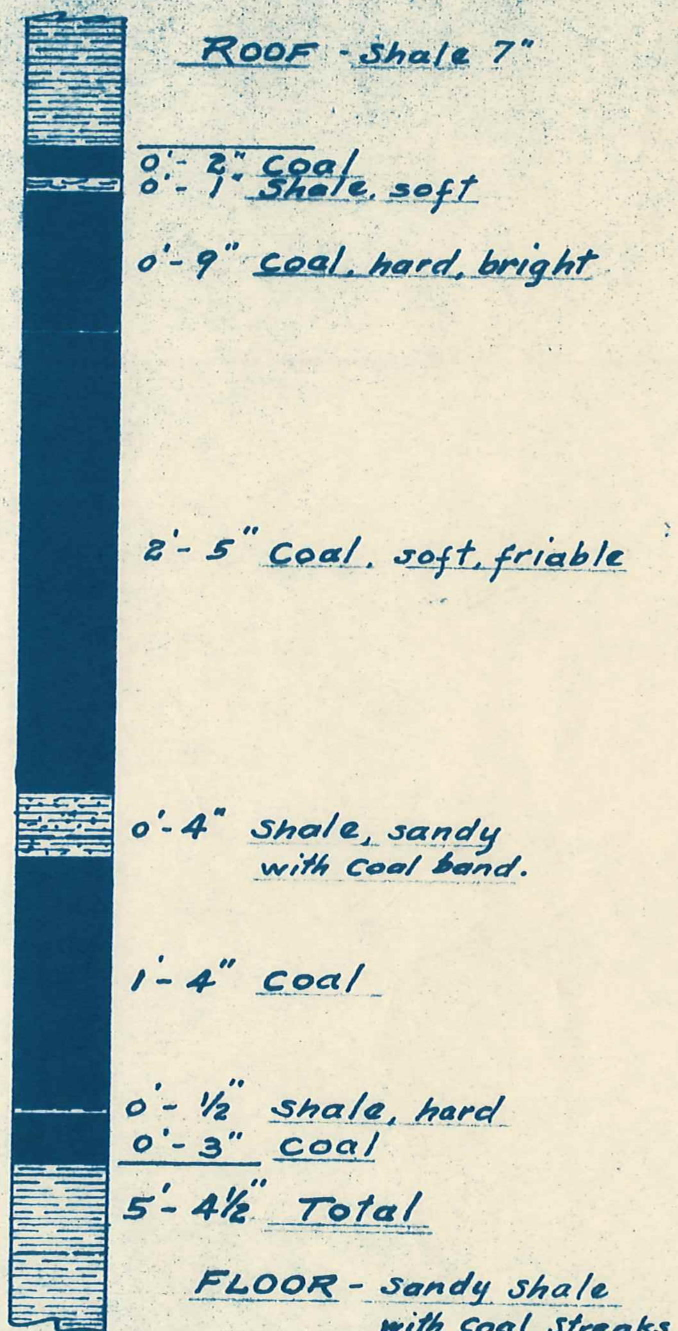
Stratigraphy of Coal Beds

In the upper 1,200 feet of the Roslyn formation occur the important coal seams. Most of the mining in this field has been and is now in the Roslyn bed, but several companies have worked the Big seam which lies 210 feet above the Roslyn. At present, the Roslyn-Cascade Coal Company and the Northwestern Improvement Company are working both seams.

The Roslyn seam averages 4-1/2 ft in thickness. It is generally overlain by a bed of shale, but at times by a heavy friable bone, varying from 3 in. to 2 ft in thickness.

Figure 2

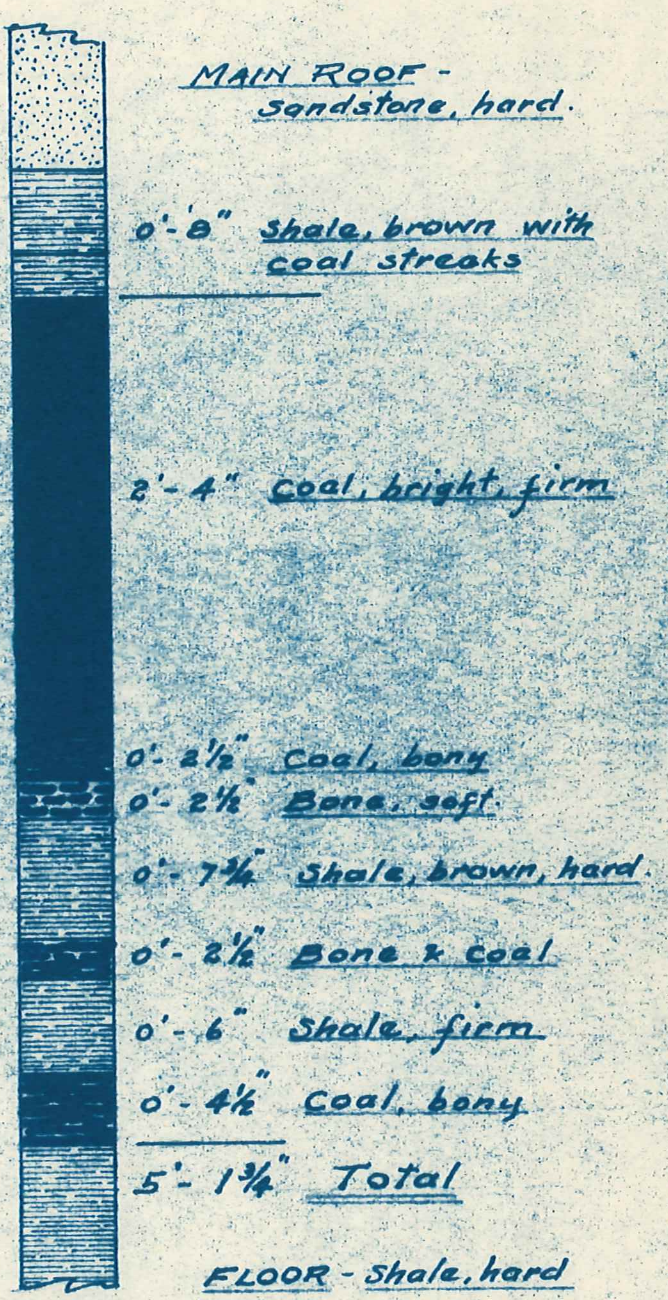
ROSLYN SEAM



ROSLYN No. 3 MINE
PIONEER ENTRY
August 25, 1938.

Figure 3

№ 3 SEAM



SECTION IN ROCK SLOPE BETWEEN
RONALD № 2 AND ROSLYN № 3 MINES
April 4, 1939

Natural Geological Subdivisions of the Coal Field

a. Ronald Area

The northern end of the Roslyn-Cle Elum coal field contains the small town of Ronald, Mine 3 of the Northwestern Improvement Company, and all the independent mines operating in the field, with the exception of one small truck mine near Cle Elum.

The dip of the strata in this area is low, and is very even. The development work and the operation of the mines in this upper part of the field are systematic, so that the problems of mining have until recent years been very simple.[2] With the development of the synclinal basin and the anticlinal workings, the bigger part of the mining complexities met in this field are now undergoing prospecting and solution at Mine 3.

The coal in this area has undergone more metamorphic changes than that of the central or lower part of the field. The agglutinating values found in the Roslyn seam are well developed here, and the coal is classed as of coking grade. Slightly higher calorific classification and lower ash content are features characterizing the Ronald coal from that of the other two sections.

b. Roslyn Area

The coal in the Roslyn area is classed as slightly coking. Sharp strata-dip changes occur in the deeper workings in this area, and in the east side workings of Mine 5 the maximum dip of 54° is reached. Mine 9 is in this area, but is situated upon an anticlinal dome. The dips of its new workings are close to 40°.

c. Cle Elum Area

The only productive operation in this area at the present time is a small truck mine working near the outcrop line. Ridge workings have been extensively carried on, and much of the eastern anticlinal flank coal was extracted by the Northwestern Improvement Company in Mine 7.

The coal in this area is the least friable in the field. Experiments on coal from the old Mine 7 gave an average friability of 41.8 per cent, as compared with an average of 47.2 per cent from coal of the Mine 3 in the northern area of the field.[10] Near Cle Elum the coal is banded or laminated and breaks with a splintery fracture; at Ronald it is denser and less banded, and the fracture is somewhat irregular, and cubical.[6]

While the relative gram aglutinating value of the Mine 7 coal is zero, the Mine 3 coal value is 5,060. Coal from the Mine 5 of the Roslyn area of the field averaged 1,420, and coal from the Mine 9, slightly north of the Mine 5 in the Roslyn area, tested 2,040.[10]

MINING GEOLOGY

Depth of Present Operations

The depth of present operations of the Northwestern Improvement Company ranges from 3700 ft to 500 ft above sea level. The Townsend or pension mine and some old slope pillars being recovered are the only workings on the ridge at the higher elevations. The lowest workings are the synclinal basin workings of Mine 5, but this depth had been reached previously in the old Mine 7.

Up to around 1925, conditions had been very favorable for mining in the Roslyn field. The seams down to the 2200-ft elevation had been on low and even dips with a cover of from 200 to 250 ft. The Teanaway hillside workings finished up, and depth operations took their place.

The operations of Mine 5 at the 500-ft elevation are under approximately 1800 ft of cover. The workings are under great stress, due to the pressure but also to the nature of the stratum underlying the Roslyn seam.

Footwall heaving causes much upkeep on trackwork at depth. The fireclay expands, and the swelling must be dug out. At Mine 5, the basin slope has not been affected since the initial swelling was removed, but in the old Mine 7 the bottom had constantly to be dug clear. The swelling was so continuous that basin workings had to be discontinued.

The fireclay in Mine 7 was thicker than in No. 5, but more open ground surrounded the haulageways, due to the old advancing system of mining had been in effect in No. 7, perhaps the limitation of working could have been coped with for a while. Because the upper coal had all been extracted, the life of the mine was limited, so that further outlay for coal cutting and conveyor equipment could not be justified.

Timbering Methods and Caving to Relieve "Riding"

All mine posts are supplied, already pointed on one end to help cope with the fire-clay heaving. The fire-clay rises then around the timbers and does not split and crack. Soft-wood crossbars and cap-pieces above the posts compress in the squeezing, and help to save the timbers.

Stable roof conditions are sometimes met over extracted rooms, so that the planned pillar break-line cannot be secured. The open hanging wall will bow and will ride the nearby live workings and their timbers, causing dangerous conditions. In such cases, roof blasting and timber pulling are effected, to secure the necessary pressure and weight release. Oftentimes the footwall shifts and warps, causing timbers to get out of line.

Another great factor in the severe footwall and hanging-wall conditions met is the anticlinal and synclinal fracturing. Fractures may be seen as deep as 100 ft and with an opening of 6 in. on the fold. Timbering must be heavy, and, in basin and anticlinal areas, must be placed with exceeding care.

On the steeper dips, in development work, the lower-entry timbering was found to have suffered more than the upper counter air-course entry. The force vector seemed to center

Plate III. Mine 5, 13th East entry, temporary timbering. Note timber breaking from pressure although entry has been driven but 10 days previously through this area; 1640 ft overburden.

Plate IV. Mine 5 13th East permanent timbering.

on the low side posts of the entry, as was commonly found with old mining methods used in the past on the steep dips. On the old contract advancing system, airways were driven below the haulageways, and trouble was experienced in keeping them open. Now, under the retreat system with the airway directly above, any sort of trouble on the entry would immediately affect the haulage.

As a result, experimentation has recently brought out a modified three-entry system, one of its advantages being better roof control. The same 14-ft-high counter-airway is driven, but entry instead of being 14 ft, is now 24 ft. This wider adit acts like the old advancing entry with its low-counter airway, in that roof pressure centers on the lowest timbers. A heavy rock gobbing acts as did the coal pillars of the old system, between the entries (Plate I). In the low-dip development work under the mechanized retreat system, wide entries had previously been driven, and the timbers over the haulageways had suffered less than previously, under the narrow work.

Retreat System to Avoid Squeeze Over Live Workings

From the opening in 1886 until 1927, miners had worked by the old hand-contract method--using pick and powder, laying track into each working room, loading coal into the cars, and sending them when full down the entry to the main slope to be hauled to the surface. The men were paid according to the tonnage dug.

This system worked fairly well in areas above water level, where the roof overhead was thin, from 20 ft to 250 ft. But, as they dug deeper and the overburden increased to hundreds of feet, the miners encountered trouble. Under the tremendous pressure of countless tons of rock and earth, the insides of their tunnels began to misbehave.

Where the floor was soft, bottom heaving would so bulge the track that cars could not enter or leave the rooms. Occasionally men would have to dig their track deeper once or twice during an eight-hour shift. Where the floor was hard, supporting timbers would break.

If the miners succeeded in digging the coal from the rooms, when they returned months or years later to extract the pillars of coal left standing between them, they would find the timbering decayed and the rooms clogged with fallen rock. Recovery of the pillars proved expensive; much coal was lost because the extraction often proved more costly than it was worth.

The change began in 1927.[5] Mine officials experimented with a short wall coal-cutting machine. This proved highly efficient. Soon more machines followed. Then came the jig conveyor--a long, reciprocating chute for carrying the coal down from the rooms to empty cars waiting on the entry track below. Many important changes accompanied the influx of the machines: speed of coal output shot up, costs of producing a ton of coal dropped, miners abandoned the tonnage-contract system of pay and adopted a day-wage rate; the advancing system of mining was discarded as the retreat system took its place.

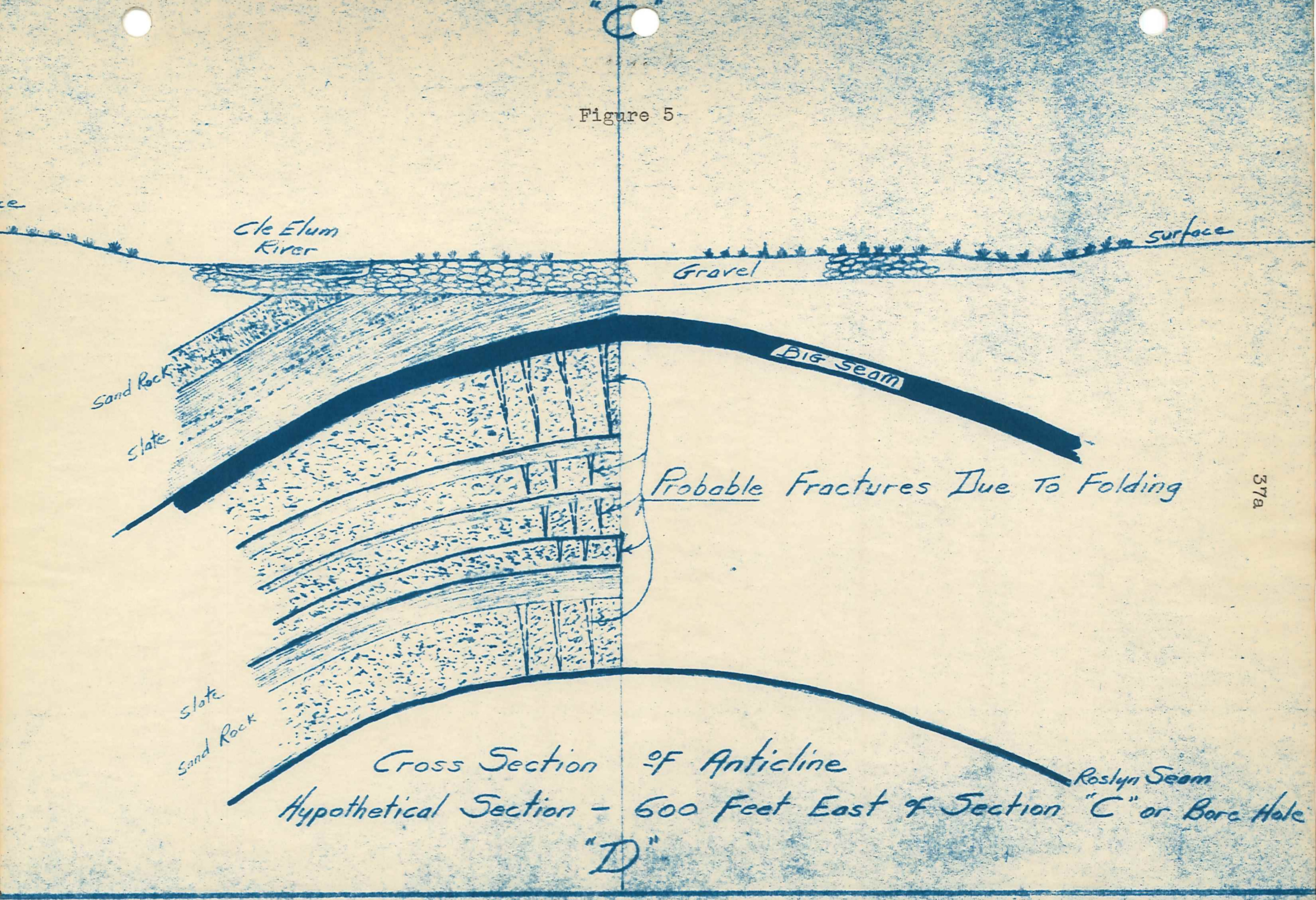
The arrival of mechanized mining had its effect on safety records.[1] In hand-method days, pick-swinging miners who failed to wear goggles suffered eye injuries accounting for one of every ten non-fatal accidents and accounting for 7-1/2 per cent of the time lost from work during the year. The machines reduced such injuries to a minimum. Other advantages of mechanization were fewer man-hours of exposure, better ventilation, safer blasting, less danger from roof falls away from the face, closer timbering, and fewer haulage accidents from runaway cars, derailments, and loose track.

The machines, however, brought their own hazards. The roar of the jig conveyors prevented men from hearing the warning cracks of breaking roof. More coal dust had to be wet down, more rock dust used, better ventilation arranged. Stricter supervision was required, and the bunching of workers in the mechanized system made supervision easier.

Anticlinal Nose Prospecting at Mine 3

The long and deep workings of Mine 3 extend well upon the eastern flank of the anticline. As the axes of the folds are on a slight pitch, an entry could be driven, on grade, around the ridge of the anticline without coming out to the surface -

Figure 5


"C"
Cle Elum River
Gravel
surface
Sand Rock
Slate
Big Seam
Probable Fractures Due To Folding
Slate
Sand Rock
Roslyn Seam
Cross Section of Anticline
Hypothetical Section - 600 Feet East of Section "C" or Bore Hole "D"

a necessary feature, because of the Cle Elum River flowing above the western flank of the anticline in the Ronald area of the field. The adit, known as the Pioneer entry, resembles in plan view the outcrop of the anticlinal nose. From the prospecting thus made possible, adequate plans are being made for the systems to be employed in the Ronald area.

Principal plans concern control of the river. At the present time the belief is that workings can safely come within 250 ft vertically of the river bottom. Before that distance is reached, underground diamond-drill test holes will be put up into the overlying strata to observe drainages. The blue glacial clay sealing and the river sediment sealing can be studied by means of the diamond drilling.

Pillars will be left according to experimental results, and if in the future back-filling is decided upon, material from the old rock dumps at Ronald will be sluiced into the opened ground.

Mining Factors as Related to the Varying Dips

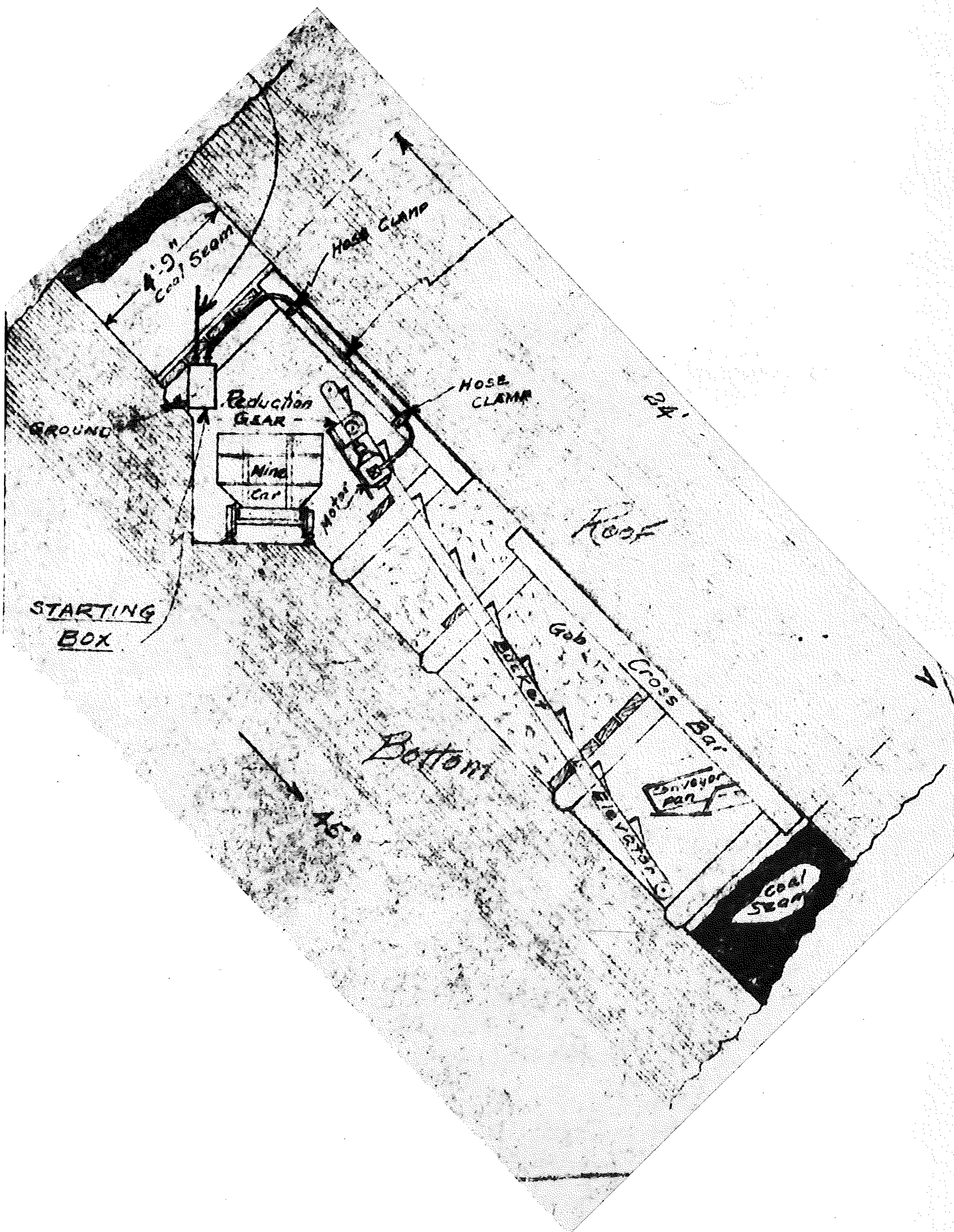
Success of the mechanization program depends upon adaptability of the machinery to local conditions. The Northwestern Improvement Company's adaptation of machinery has been constant, but although many systems and improvements have been worked out, because of the geological conditions, machinery cannot be brought to the coal as easily upon the steeper dips.

The following statistics compare results of the workings on the higher dips to those upon the lower in Mine 5, during 1939.

Dip	Tons per face-man	Tons per timber (Crossbars and props)	Rock brushed
24°	5.00	Development work	2.0 ft
40	6.70	2.04	3.5
42	6.63	Development work	3.5
8	9.27	3.43	2.0
10	9.58	4.89	2.0

With the advent of the elevating bucket conveyor and a new system of development work on the steep dips, introduced in December, 1939, the tonnage figures for the entry driving have materially increased. But the difficulty of handling the machinery, the need for more timbers and lagging, and the greater amount of rock brushing required on the steep inclines, have led to two generalizations: (a) in low coal seams the amount of tonnage output per man at the face is inversely proportional to the dip, and (b) both the number of board feet of lumber used per ton of coal extracted and the amount of rock brushing on haulageways are directly proportional to the inclination.

Figure 6



FRONT VIEW OF DEVELOPMENT WORK ON DIPS OVER 30°

MINING

MECHANIZED MINING AND MACHINERY

The Roslyn Mechanized System of Mining

All mining done by the Northwestern Improvement Company in the Roslyn field is carried on by machinery, with the exception of steep dip incline or slope driving and the operation of the old men's "Townsend Mine". On the steep inclines coal will run by chutes, but on steep-slope driving the inclination is too great to permit effective handling of coal with conveyor equipment. The pension mine uses the old hand-contract system, to favor the old employees who spent their working lifetime on that system. Under this system the men are paid by piece work, and so may work when they wish, starting and quiting the day's work at their own convenience.

The mechanized system of mining requires men skilled in the handling and maintenance of machines. With the development of mining systems adapted to the natural conditions in this field, the only heavy manual labor required is that needed to install and move machinery. Most of the moving of machinery is done with haulage motors, or with stationary electric timber hoists and a rope and sheave. At the working faces, conveyors and segments of the pan lines are moved by use of the mining-machine rope drums. Air and electric tuggers move the lighter equipment.

Free mining of the coal is secured by keeping the wide working faces parallel to the cleats of the coal; the roof and bottom squeezing pushes it out. It falls into the first line of pans, which are only one-sided and are aligned at an angle to guide the coal down to the swivel and the two-sided pans.

On the steeply inclined workings, this practice becomes dangerous because of the falling rather than the sliding of the coal, and accordingly is not used. But the increased gravity factor takes the coal from butt faces down to the pan line without any manual coal handling except for drilling and blasting.

Entry work on the steeper inclinations finds the coal sliding down the wide face of the haulageway to jigging conveyors that load into bucket elevating conveyors. These chain-and-flight conveyors bring it up to car-loading height. On the low-dip entry work, the shot-down coal is scraped up by the one-sided face pans of the conveyors, drawn underneath it by the drum ropes of the mining machine.

In every mining system, the conveyors are started before any blasting or loading is begun. After the blasting, much of the coal is loaded out automatically, the men keeping back from the workings while the smoke and dust are clearing out.

Shearing machines are used on the heavy dips, because of the difficulty and danger of taking a shortwall undercutting machine up the hill.

Coal loading is concentrated everywhere in the mines. The entry and counter-entry conveyor spouts load into the same coal car on low-dip entry work as do the elevating conveyor and the counter chute from the conveyor above on the steeper dips. Rooms and pillars in the flatter areas load into the same trips of cars, but in the "pitching" areas the pan room and pillar workings load into the central-raise chute, under which each car of a trip is quickly filled.

Crew sizes range from 18 men on development work for the double-shift day to 21 men for the single-shift day on 2-room and 2-pillar entry work. The classification is as follows:

Crew Required in Entry and Counter-Entry Work
(Double-shift day; total of 18 men)

2 district foremen (one a shift)
2 conveyor runners (one a shift who runs both the entry conveyor and the counter conveyor or chute)
2 trackmen
12 face men: 3 at a face
- 1 machine runner
- 1 timberman
- 1 loader

Each crew independently loads, cuts, wets down, timbers, and rock-dusts. In each shift, during the lunch hour, one man rock-dusts with a portable blower that attaches to the coal-drill air lines.

Crew Required for Entry Production Work
(Single-day shift)

1 district foreman
4 conveyor runners
2 machine runners
4 timbermen
4 duck-bill men
6 loaders

Speed obtained by mechanization is an average of 350 ft per month in development as contrasted with 100 ft of advance made by the old hand-contract system. If necessity requires, development work by mechanization can be pushed to 500 and 600 feet per month. A 600-ft airway connection between Mines 5 and 9 was driven on one conveyor setting by triple-shifting on the five-day working week.

Tonnage figures average over 9 tons per man for all inside men at the working faces. In some rooms which have been opened up well, so that the coal is working freely, 20 or 25 tons per man has been secured. In older workings, however, the longer haulages, greater amounts of bottom brushing on trackways, and of timber setting in the mines, and slower production secured on the high-dip workings, appreciably reduce the tonnage per man of the mine as a whole.

Typical tonnage figures are these secured at Mine 5 by the writer during one summer's work:

MINE AVERAGES FOR INSIDE MEN

1409.33 tons per day
215.87 men per day
6.22 tons per man (1)

	Tons per face-man	Tons per man
Mine 5	7.4	9.12
Townsend Mine (2)	3.34	4.2
Two Mines	6.52	8.01

Types of Machinery Used

a. Undercutting Machines and Shearing Machines

Four types of mining machines are used in the Northwestern Improvement Company mines: Jeffrey, Sullivan, Goodman, and the home-manufactured. All the machines are permissible, and most of them are 50-hp, a-c types. The home-designed machines are of the shearing type, which utilizes a hydraulic forward motion and a hydraulic raising cutter bar. This was designed for use on steep-dip development and incline work, and in rooms where the coal is working freely and only the tight corners have to be slightly cut. The hydraulic cutter bar is utilized in lifting and holding the crossbars against the hanging wall before the installation of the collar legs. Models used are the following:

1. Counting 160 man-shifts of idle-day work over the month.
2. A small block of coal on the water level of Mine 5 was opened up for the older employees of the company. This is known as the "Townsend" mine.

Plate V. Roslyn seam at Mine 9 on a 40^{o} dip. Sixteen ft timber sets on 5 ft centers. About 50 cars of rock brushed per set.

Plate VI. Shearing machine at face of the 13th East counter entry, No.5. Notice leveling-skid and the machine's hydraulic forward mechanism.

MINING MACHINES - ALL PERMISSIBLE

MANUFACTURER	TYPE	HORSEPOWER	CUTTER-BAR LENGTH IN FEET
Home-manufactured	Shearing	20	7-1/2
Goodman Universal 512 112 A.A. 250 d-c 440 a-c (Some early models rebuilt by the Northwestern Improvement Company)	Shortwall Undercutter	50	7-1/2
Jeffrey 35 BB 440-volt a-c	Shortwall Undercutter	50	7-1/2
Sullivan (Buddys) 5B	Shortwall Undercutter	10	6

b. Overdrive and Underdrive Shaking Conveyors and Elevating Conveyors.

All conveyors used in the mines are home designed and manufactured. The overdrive and underdrive units are given a reciprocating motion by a permissible 440-volt, a-c, 20 hp motor. The speed of the conveyors can be adjusted from 60 to 72 strokes per minute by a simple change in size of the belt drive pulleys. The length of the stroke is 6 or 8 in., dependent on whether the shaft "heart" contains a keyhole with a 4-1/2 in. or a 6-1/2 in. center. Conveyors of late are belt-driven, but earlier than 1938 they were equipped with silent-chain drives. More maintenance was required with the chain drive, but in changing the pulleys a link could easily be knocked out to slow down the conveyors for the more steeply inclined room dips.

The home-cast shell ends of the permissible conveyor motors are designed for water cooling of the motor. The conveyor drive heads are of heavy iron and riveted construction, containing extra heavy cast-iron babbitted bearings and nickel-steel shafts. Drive "hearts" and side arms are of heavy cast iron; drive arms are of heavy iron with brass bearings; all gears are completely enclosed and run in an oil bath.

Little change is required in the conveyor drive unit to make it into either the overdrive or the underdrive type. For an overdrive unit, the drive arm is pointed up and out of the conveyor head; for the underdrive, the arm "kicks" out from the drive head between the bottom part of the frame and the lower part of the machinery. In this latter case the drive arm must be made several feet longer.

The only advantage of the overdrive conveyor is coal-loading height. To gain that height wood cribbing must be placed in and graded under the first four or five pans of the conveyor line. The low underdrive conveyor does not get out of line nor develop a whip as easily as does the overdrive, because its pan line does not contain the sharply graded portion. This latter conveyor is very effective on all chute loading work.

The standard pan section for these two conveyors is made of 30-in. sheet steel, No. 10 gauge; it is 10 ft long, and weighs 272 lb. All standard pans are made from full sheets of No. 11 gauge tank steel, 30 in. by 120 in.; they measure 14 in. across the bottom, 17 in. across the top, and 8 in. in depth. On entry and slight-slope work, the first four or five conveyor pans are 22 in. by 14 in. in top and bottom widths, so as to handle the usually slower moving and consequently greater accumulations of coal in the pan line.

Conveyor units on all haulageways are aligned along the low side of the haulageway, and loading is done by use of a turn pan connected to the drive pay. Conveyor heads of pan lines pointing up the dip are installed on the high sides of the gangways, and load at right angles into the trip cars. Conveyor drive heads are anchored by means of 1/2 in. iron screw jack-pipes which are 2-3/4 in. in diameter.

Bucket-elevating conveyors are a recent addition to the coal-conveying equipment. They work in conjunction with the overdrive jigging conveyors on the steep-dip gangway work. Their addition has allowed wider haulageways to be driven, which not only produce more coal from development work but which also provide rock-gobbing room for the great amount of rock brushed in the 4-1/2 ft workings of the Roslyn seam. Home designed and manufactured, they are 18 ft long and 2 ft wide, and are driven by a Westinghouse 7-1/2-hp, 440-volt, permissible motor.

c. Air Drills and Electric Drills

Most of the coal drills in the mines are of the auger type and are air-driven. Electric types are rapidly being displaced by the lighter and safer air drills. The Ingersoll-Rand and Chicago Pneumatic auger-type air drills are 4-cylinder, butterfly-valve types requiring 90 lb of air. Ingersoll-Rand jackhammers are used for the heavy haulage-way rock-brushing, and two automatic stopers, manufactured by the same company, are used on any rock tunnels required.

d. Air Tuggers and Electric Timber Hoists

Small air tuggers and timber hoists, made by various manufacturers, are temporarily installed in working places to transport light supplies. Permissible electric timber hoists are installed in the heavily "pitching" areas, to take the heavy machinery and supplies up the raises. Some small home-made tuggers are run off the shanks of the air drills.

Roslyn Field Adaptations

a. Guards and Skids for Steep Dip Workings

Shortwall undercutting machines are surrounded by guards which are attached by bolts, and so are removable. These accessories protect the drums and levers from hanging up on timbers and obstructions. Levers inside the guards are lengthened and adapted so that the machine runner can better handle his machine, and also protect his hands. The shearing machine used in development work is fitted on its low side with a

Plate VII. Rear view of the shearing machine.

Plate VIII. Undercutter with guards in a panel room. Note the Northwestern Improvement Company guard around the sumped in "Buddy" Sullivan machine.

heavy steel shoe which keeps it very near to its normal upright position. This shoe is built in the form of a skid which guides the machine forward. The cutting bar has a universal-joint timber-holder accessory that is used in lifting and holding up the crossbars.

b. Reinforced Pans

When the first Northwestern Improvement Company pan lines were used on the uneven grades, the heavy thrust of the uphill stroke gave the pan lines a tendency to buckle, which tendency was counteracted by a 16-lb steel track rail welded along the undersides of the pans. On very uneven and warped bottoms where the pan lines will still get a tendency to buckle, pan boards of 2 in. by 6 ft timber across the joints hold the conveyor line in shape.

c. Wedge Couplings

The first fasteners of the conveyor pans were bolts and nuts. The bolts would jam or would work loose, and sometimes would be loaded out with the coal and would get caught in the locomotive stokers. This occurred before the central washer was completed. A link-and-wedge coupling was devised which not only proved quicker and easier to fasten, but could be fastened to the pans themselves and so could not be misplaced or lost. The wedge fastener proved much more flexible in the horizontal alignment of the conveyor line, and its working in conjunction with the cradle rollers and rockers gives what is believed to be the most flexible conveyor for uneven and warped mine bottoms. A bolt-coupled pan line, like a belt conveyor, must not be out of grade or out of horizontal line, but the conveyors with the previously mentioned couplings and rollers are easily adapted to severe conditions.

Conveyor cradles can make a decided difference in coal movement. Often when coal is not moving as well as it should, putting the bottom part of the cradle a couple of inches forward toward the conveyor expedites the operation. This procedure is especially effective on low grade or level work, but not up the pitch.

d. The Roslyn One-Sided Pans

Perhaps the most outstanding feature of the Roslyn conveyor system is the use of several one-sided conveyor pans at the working faces rather than "duck-bills" or automatic loading devices. Experience has demonstrated the inadaptability of hydraulic and ratchet duck-bills, Y-branch pans, and cross-drive conveyors on the variable dipping ground in the always closely timbered workings. The flat pan is simply a standard pan with one side down, forming a wide-bottomed loader. Either in panel rooms or in rooms up the dip, these face pans run across the inclination or else are angled on the "pitch". Coal sliding down the dip runs into the pan against the one low side, and this side guides it down the wide bottom to the normal standard pans.

On the low-pitch entry driving, from the swivel to the face, the one-sided pans are pulled underneath the shot-down coal by a mining-machine drum rope, thereby scraping up the coal. In most cases, the only hand shoveling required is that of coal that sluffs under or falls over the pans in the entry-scraping or in the room-guiding loading methods. The adaptation of these wide, one-sided, guide face-pans has proved that the stationary conveyor set-ups can be made very flexible from the swivel to the end face-trough, for the purpose of not only conveying but also self-loading the coal.

e. Conveyor Accessories

When conveyor lines on inclinations over 20° begin to get long, springboard counterbalances stationed at intervals along the pans greatly aid the motor in thrusting them up the hill. The springboards are simple homemade arrangements on the cantilever principle, with the baseboard of 4-in. lumber, 1 ft wide and 12 ft long and with the series of boards each 1 ft shorter than the one preceding. The truss is equipped with a take-up screw on one end, a stull is used as the pivot, and a hook from the other end springs the pan line up the hill.

Although the conveyor speeds and stroke lengths are decreased on the conveyor lines running up steep inclinations, chunk coal will still boom down the pans unless coal checks are placed in the trough units. Swinging objects such as suspended weights will be knocked out of the pans unless stationary boards, 1-in. by 12-in. by 16-ft and with a light weight on one end, are suspended in the pan line. The weighted board end collects coal under it until the accumulation raises it and slides on under.

MINING METHODS

Development Work on Dips Under 30 Degrees

The entry-face system on the low dips is as follows: The conveyor face-pan is pulled back to give room for the mining machine to sump in. The machine cuts half the face, and is left in place while one man cleans out the cut. Two holes are drilled, the face-pan is pushed into the cut, the conveyor is started, and the shots are fired. After the smoke has cleared, the men wet down, and a couple of them clean up the coal behind the pan line while the others finish the cut.

The mining machine now at the other side is pulled back and anchored. The rest of the face is shot down, the coal is sprinkled, and the rope from the nearest machine drum is attached onto a face-pan eye hook about 8 in. high, welded a few feet back from the flat end of the last one-sided pan. To this hook is fastened one rope from the drum of the mining machine, which is set in lowest gear. As the conveyor loads the coal out, the pan line from the swivel to the face is slowly pulled under the shot-down coal. The loaders follow the pan line, scraping up the remaining coal. The angle of the hook as well as its height is adjusted to local conditions; otherwise the line would either pull out of the coal pile or else dig into the bottom.

Entries are driven 24 ft wide to give coal tonnage on development work, better timber storage, and less trouble from air-ventilation obstructions. Although a wider entry gives more air-rubbing surface, a water-gauge drop is secured from removal of car obstructions in narrow entries. Entry-timber pressure is also lessened.

Two crossbars, 12-ft by 8-in. by 4-in., placed end to end to cover the 24-ft entry and set at 4-ft intervals, are the haulageway timbering units. Four 5-ft rounds are usually required to the unit. The counter airways, which are driven 14 ft wide, are timbered with a collar 12-ft by 4-in. by 8-in. with two posts on 4-ft centers.

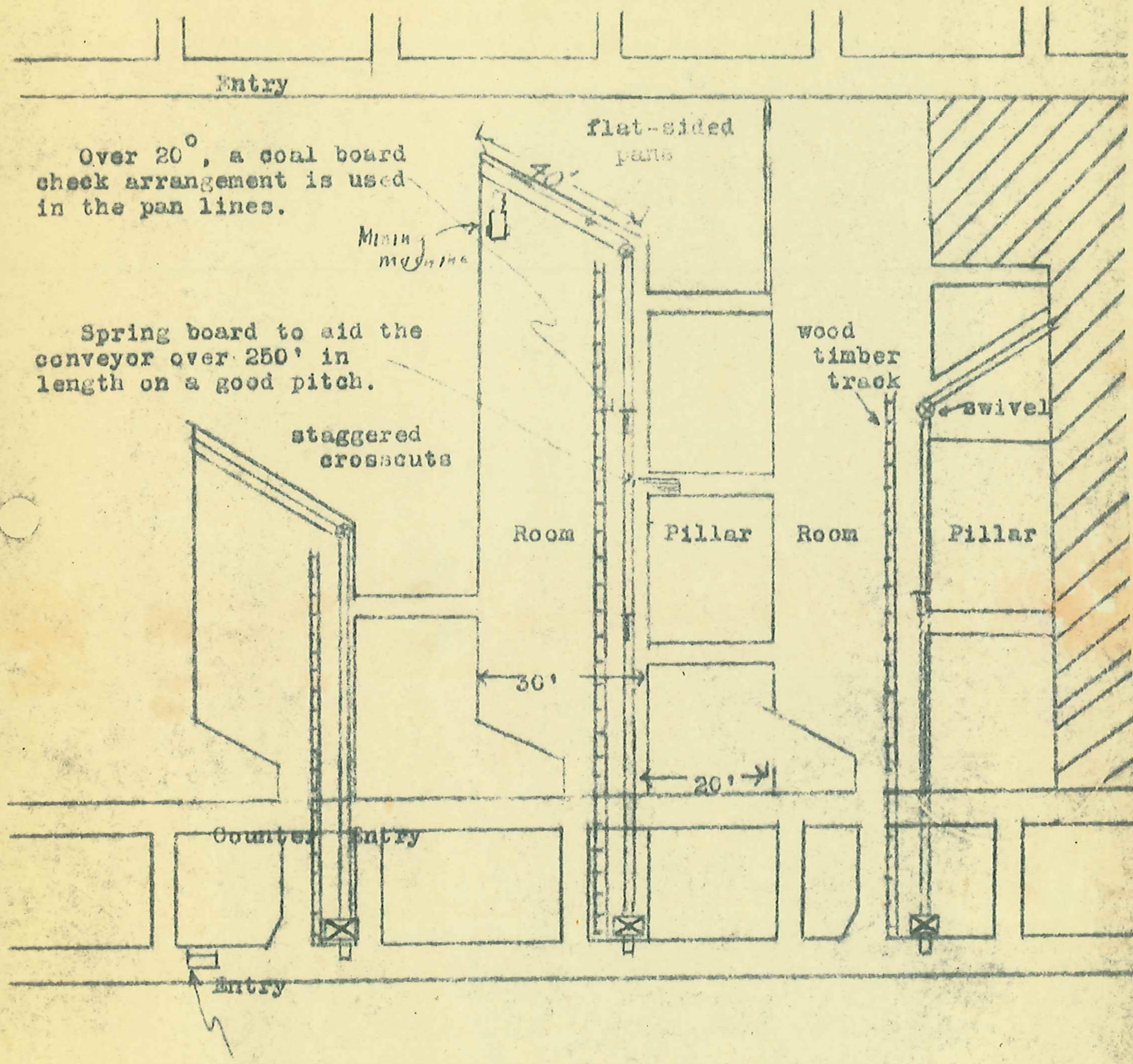
Room Work on Dips Under 30 Degrees

The common room-and-pillar system is used on the lower dips. Shaking conveyors extend straight up the dip and load at right angles to the haulageway. Rooms are driven 30 ft wide, leaving an average 20-ft pillar, but a 40-ft mining face is utilized that runs parallel to the cleats of the coal. Off the lengthwise-extended conveyor line, a swivel angles four one-sided face-loading pans along the free-coal mining face.

As the workings are now under considerable cover, the

Figure 8

ROSLYN SYSTEM ON 29° AND UNDER



One timber hoist for all of the rooms. Each room has its timber truck and cable. The hoist is stationary, with a hook on its rope to hook onto the room ropes.

roof pressure helps greatly in pushing and breaking large chunks of coal out into the face pans. Because of the low inclination the working coal falls into the pan line by gravity. The high or tight corner of the coal face is kept ahead either by a cutting machine or by a pick miner, and roof pressure does the rest of the mining. Some rooms have been driven their entire length without more than two pounds of powder being used throughout.

Two rooms and two retreating pillars are worked at one time on an entry, with two rooms turned off. When the room is being driven up the dip, the slanted or angled pan line of four units is turned in the opposite direction to the abandoned old entry workings. When the room has reached its full length, the pillars are pulled by simple angling of the face pans in the direction of the extracted ground, and by dropping of the conveyor line down the dip as the pillars are removed. By these methods rooms are always driven in solid coal, with the pillar facing the old and open caving ground, and as they mine the pillars on the descent the men are always working away from the open ground.

One timber hoist on an entry will handle all the supplies for the pair of rooms and the pair of pillars. Each room, and consequently each pillar, has its own timber truck and cable. The hoist is stationary, with a hook on its line to attach to the room ropes.

Inclinations over 20° require two conveyor accessories.

A springboard of the cantilever type aids the conveyor motor in thrusting the conveyor line up the inclination, and in preventing buckling. In the pan lines a coal-board-check arrangement is used to prevent the coal from running down the pan lines too fast. Conveyor motor speeds are also slowed down, and the length of the conveyor strokes is shortened.

The rooms are timbered systematically, props being placed on 4-ft centers, with at least four lines in each single room. Cross-bars are generally placed over conveyor line, manway, and timber track, but in many cases cross-bars are used throughout the room and pillars. In some instances cap pieces placed above the props are sufficient. Props are kept right next to the working face, often between the conveyor face pans and the coal. If the roof is treacherous, the face flat pans are broken up in order to be moved up next to the coal.

The cross-bars are 8-in. by 12-ft rough lumber, either 3 or 4 in. thick. Round timbers are usually unpealed, and are from 8 in. to 12 in. in diameter. Cap-piece dimensions are 4-in. by 8-in. by 4-ft.

Development Work on Dips Over 30 Degrees

Haulage entries on the steep dips are driven 24 ft wide, but owing to the sharp inclination, coal from the shaking conveyor must be brought up to loading height by the use of bucket-elevating conveyors. Coal mined at the face runs by gravity into the shaking conveyor, which transports it to the elevating conveyor, installed at right angles to the jigging conveyor and also at right angles to the haulage track.

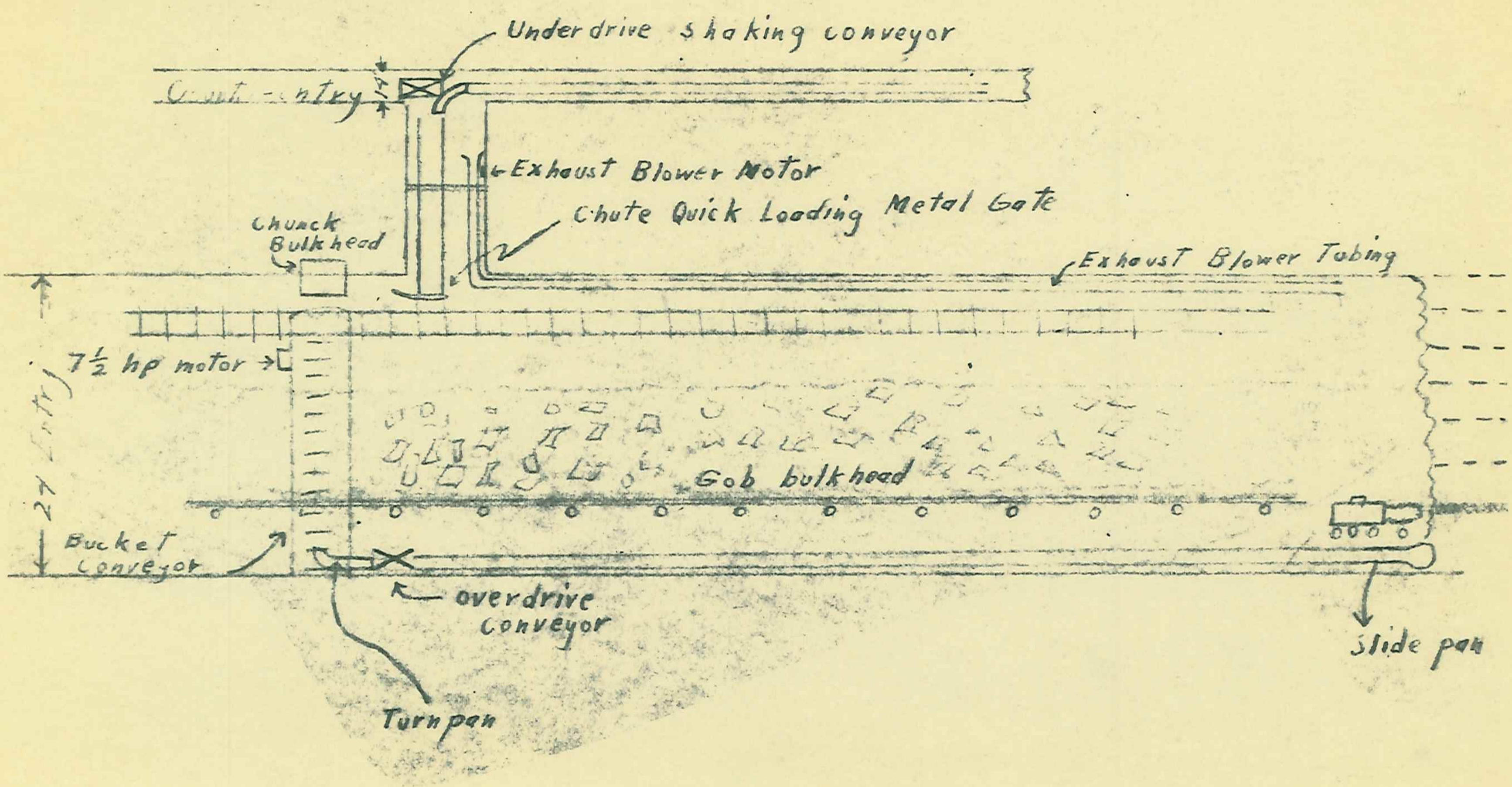
The cutting machine used is the Roslyn shearing machine that mines a vertical cut 6 ft in depth. After a cut, the machine is withdrawn, and the bottom block of coal is shot out, leaving an opening for insertion of the pan line. Drillers blast down 4-ft block slices, which slide down the dip into the face pan - a modified sliding duck bill.

Between the track and the shaking conveyor, a gob bulkhead is timbered in, and almost all the rock brushed from the haulageway is shot down against the bulk-head, thereby forming an effective chain pillar.

Before the installation of the elevating conveyor, the entries on the east side of the mine could be driven only 14 ft wide. At the end of the working week several men had to brush an average of 3-1/2 ft of rock (7 ft on the high side to ground level on the low) for a number of shifts. When the 14-ft entries were being driven, 1-1/2 tons of rock were hoisted to every ton of coal. Track work and permanent timbering were behind, brattice lines were long and in the way, and the timber supply was difficult. Practically all the gob had to be taken out of the mine; after the fifteen or so manshifts of dead work each week-end the rock had to be dumped on Mondays, and often the mine tonnage for that day would be 100 tons less because of the time required for haulage and

Figure 9

Development Work on Dips Over 30°



for handling of the tipple.

Since installation of the elevating conveyor, the coal tonnage on that entry-development work has jumped from 150 to 250 tons per double-shift day. Three more men are needed on each shift, but only a few men need brush rock on idle days. All rock is left in the mine, and the holes are so aligned as to allow the blasting of the rock down into the bulkheaded (lagged) gob space. A better drainage system is now available, and in case of a pile-up or cave-in on the haulageway, another manway is open on the entry.

Entry timbering is of 2 hewn crossbars, 8-in. by 10-in. by 22-ft, set end to end, and 5 round posts under each 24-ft long set; the wide sets are timbered on 2-1/2 ft centers. Hewn timber is the strongest available that takes up a minimum of headroom. Split lagging is used on the hanging sides. The mine workings on the steep dips are now under great cover, and the narrow development work must often be retimbered within a few days. The amount of lumber used per ton of coal mined on development work is extremely high. The mine average per ton of coal is 8.2 bfl. The airway equipment consists of a shearing machine and an underdrive jigging conveyor which loads into a crosscut chute. This counter entry is driven a 12-ft collar width.

Room Work on Dips Over 30 Degrees

Panel rooms and pillars are driven across the steep dips the length of the average conveyor-pan line, or approximately 325 feet. To machine-mine the 325-ft block of coal, a raise must be driven from one haulage entry up to that above. The machinery is pulled up the raise on a wood timber track to within 50 ft of the end of the block. A 25-ft room is started, and an underdrive conveyor is installed which loads into a large central raise-chute. The room coal is transported out by the extending conveyor until the side of the block is reached; then, the 25-ft pillar above is extracted on the retreat.

When the pillar has been removed, conveyors drop down the raise 50 ft, and a new 25-ft room is excavated. Common practice is to have a pair of conveyors working together, the upper room being kept well ahead of that below.

The light 10-hp Sullivan Buddy mining machine is used in the rooms. A home-built electric hoist is installed on the side of the haulageway to pull machinery and supplies up the raise. The big central chute is lined with heavy sheet iron to prevent the concentrated coal loading from cutting to its bottom.

All timbering is rough lumber collars, 3-in. by 8-in. by 12-ft, on 4-ft centers. Because the collar legs must be utilized as machinery and must supply supports on the steep dips, heavy unpealed rounds 12 or 14 in. in diameter, are used as the set-legs. Timber hitches on the steep "pitches" are dug at least 4 in. deep, for safety. The rounds are

Plate IX. Underdrive conveyor in a counter entry. Conveyor discharges coal into chute which lea ds down through a cross-cut to the main entry. Note bottom-sniped timber.

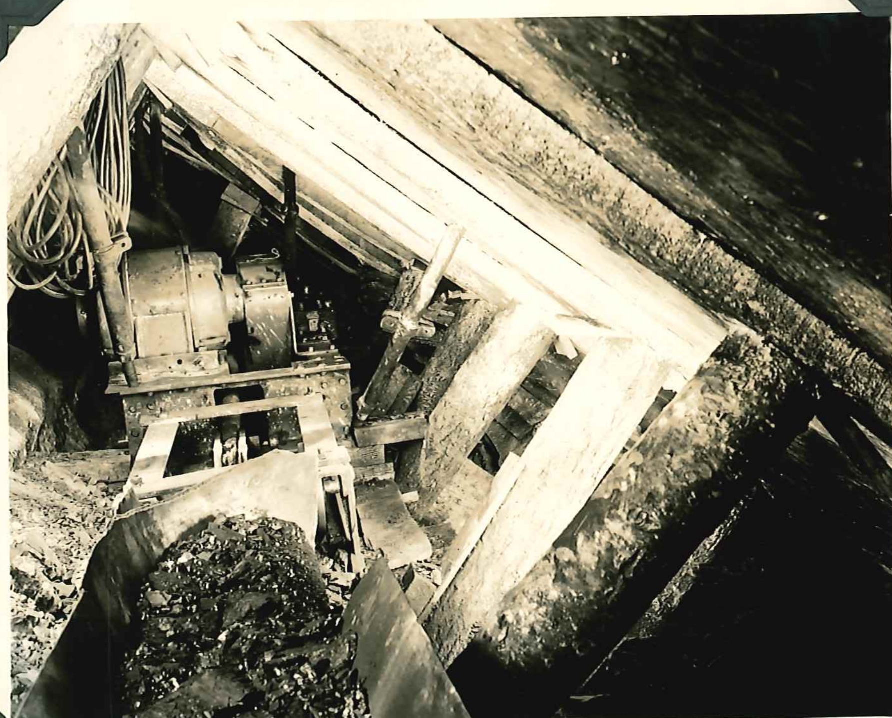
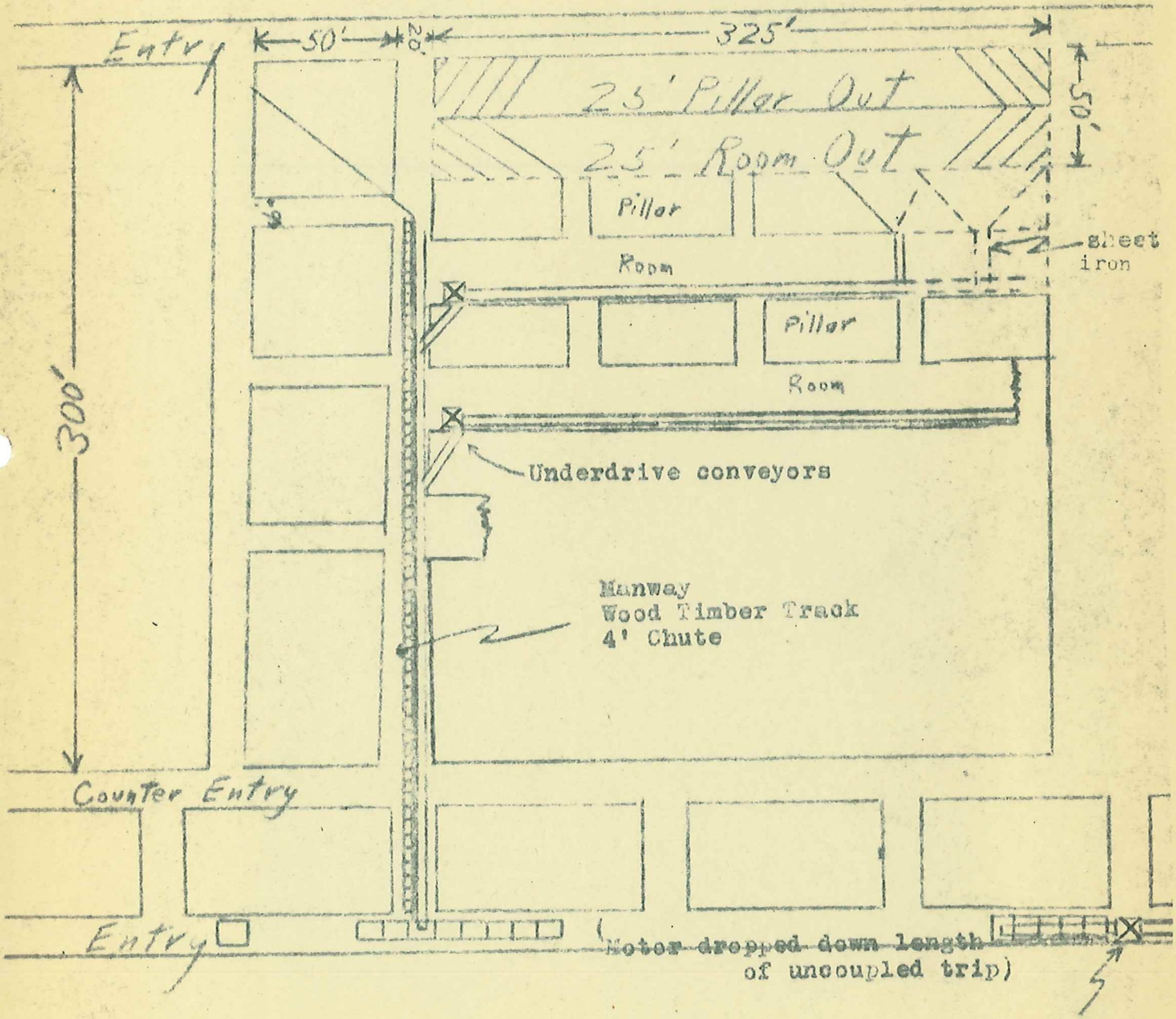


Plate X. Underdrive conveyor in a panel room. Dip is 40°.

Figure 10

ROSLYN SYSTEM ON 30° AND OVER

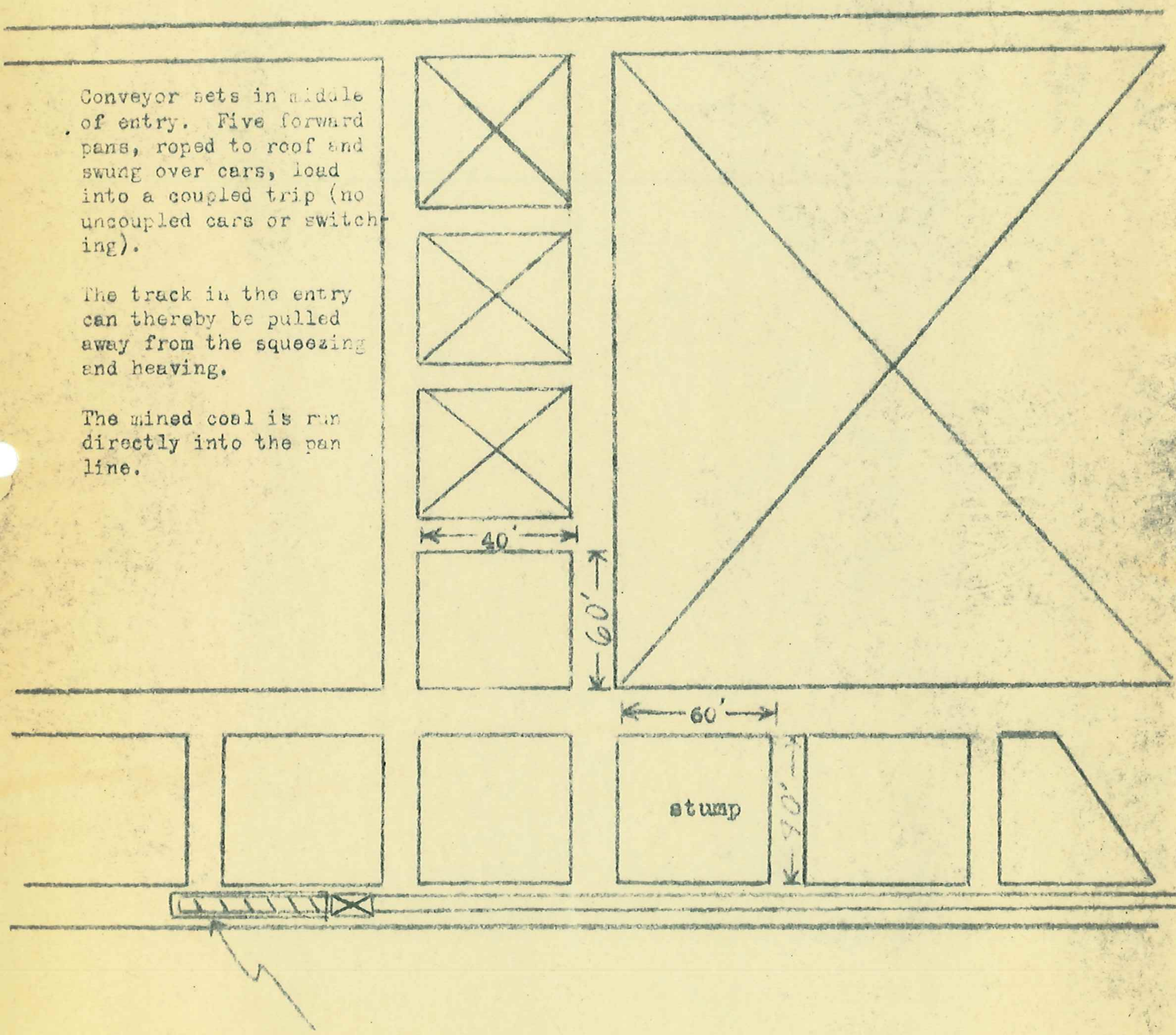
Retreat Mining System, Outside to Left



Stump recovery

Figure 11

ROSLYN RECOVERY OF STUMPS



5 pans hung in the air over cars

supplied well sniped on the bottom, to allow bulging foot-wall to come up around their bases. In some places split lagging is used on the high side.

MINE OPERATIONS

ELECTRIC POWER SUPPLY

Tie-ins with both the Puget Sound Power and Light Company and the Milwaukee Railroad give double assurance of power to the mines. The two power companies each have sources of electrical energy in both eastern and western Washington. At South Cle Elum, they transform 13.8 kv supplies to all the mines from their 110-kv lines.

At each mine, surface substations transform the 13.8-kv energy down to 2400 volts, which is carried into the mine on 3-phase single or double-knot cables. Transformers at convenient places in the mines produce the 440 alternating current that is required by the greater part of the machinery.

The 250 direct current used by trolley motors, some hoists, and a few mining machines is supplied by motor generator sets stationed at key places inside the mines. The 250-volt General Electric d-c generators are run by 2200-volt, synchronous, a-c 300-hp General Electric motors. A few haulage hoists require 500 d-c volts, which is supplied to them by insulated wire. The 525-575 volt, General Electric d-c generators are driven by 575-hp, 2200-volt a-c synchronous General Electric motors.

HAULAGE

Main Hoists and Large Ropes

The main hoist No. 3 is a single-drum Kinney first-motion steam hoist, 28 in. by 48 in. The boiler pressure pops off at 140 lb. This popping is desired before the hoist starts pulling the trip from the bottom of the mine, for a long haul will drop the boiler pressure down to 100 or 120 pounds. On the trip down, steam pressure builds up to the popping-off point. The drum is cast steel, 6 ft in diameter; the diameter of the shaft is 13 in. When the original drum cracked, the drum from the hill-mine No. 7 hoist was bored out to the shaft size, and was shrunk on the shaft by the use of turned steel rings.

At high speed, the hoist has a slight tendency to rock, and the present intention is to install tail rods to carry the weight of the pistons evenly. The drum averages about 120 rpm, and the trip averages a rope speed of approximately 2500 fpm. This speed is necessary because cars hold an average of only 2400 lb of coal, so that in order to obtain the present tonnage of 1800 tons per day many cars must be pulled. A standard trip consists of 18 cars.

The hoist develops approximately 2000 hp at 140 lb of pressure. The drum has 8500 ft of 1-1/4 in. Lang-lay plow-steel wire rope. The present rope is made by the Wire Rope and Equipment Company of Seattle. The hoist is set at a

MAIN HOISTS AND ROPES

Mine Locations	Name or Manufacturer	Steam or Electric	Number of Drums	Drum Sizes in ft.	Horsepower Motors	Revolutions per Minute	Rope Speed ft per Minute	Type of Rope	Size of Rope	Length of Rope
No. 3	Kinney & Co.	Steam	Single	6x6	1800	120	2262	6x19 Lang Lay	1-1/4	6200
No. 5	Nordberg	Elec.	Double	4-1/2 x7	800	60	1320	Lang Lay	1-1/4	3750
No. 9	Allis-Chalmers	Elec.	Double	7x8	600	53	1332	Lang Lay	1-1/4	2900

Slope Dip	Cars per Trip
170	16
360	8
360	8

slight angle, and faces the head of the slope, necessitating the use of 2 ft by 7 ft bull-wheels. Cast in the local foundry, these wheels have a replaceable steel liner, and revolve on the axle.

The boiler house has underfeed stokers and is operated only during the day shift. During the night shift and on idle days, when not over 500 tons are to be pulled, an auxiliary electric hoist is brought into service. This hoist is home-made, utilizing such local features as the 6-ft drum of an old steam hoist, pedestals cast at the local foundry, and a very efficient braking system developed in the local shop. Herringbone gears, coupled to a 250-hp 2300-volt a-c electric motor, control apparatus largely homemade that uses a reversing contactor on the primary circuit, and a homemade water rheostat on the secondary. The plates dip into the water and are connected to a lever which gives smooth acceleration, not unlike a steam throttle. When use is made of this electric hoist, the trips are smaller, 15 cars being pulled at a speed of 1000 fpm. The rope used is of 1-in. Lang-lay, plow-steel wire, manufactured by the Wire Rope and Equipment Company.

At Mine 5, the double-drum main hoist, made by the Nordberg Manufacturing Company, is powered by a General Electric 800-hp motor. The drums are so arranged that either one can be operated singly, or that both can be operated in balanced hoisting. The electrical equipment is of the magnetic contactor type, and full provision is made for overspeed and overwind devices. The control apparatus and contactor coils are on a 440-volt circuit, and the primary and accelerating contactors are of the open, magnetic blow-out type. Both clutches for the drums and mechanical brakes are operated by hydraulic oil control. An addition to the hoist, not originally installed by the maker, is an electric dynamic braking system. This was installed by the company in 1927, and is thought to be one of the first to be used for this purpose. Its use has improved the characteristics of this hoist so much that its installation cost has been paid many times over.

Before adoption of the electric brake, trouble was experienced with the mechanical brake, especially when trips were being lowered at slow speed. The brake bands and blocks would heat up in one trip, and continued use at slow speed would cause the blocks to smoke, with possibility of warping of the brake drum due to heat.

The electric brake lowers the trips with a smoothness and surety not possible with the mechanical brake. When the fact is remembered that the average pitch on the haulageway is 35° to the dip, the features of this brake can be well appreciated.

The rope speed on this hoist is 1325 fpm. The ropes used are of the 1-1/4 in. Lang-lay plow-steel. Their length on this haul is 3750 ft.

For several years, man trips were hauled and lowered on

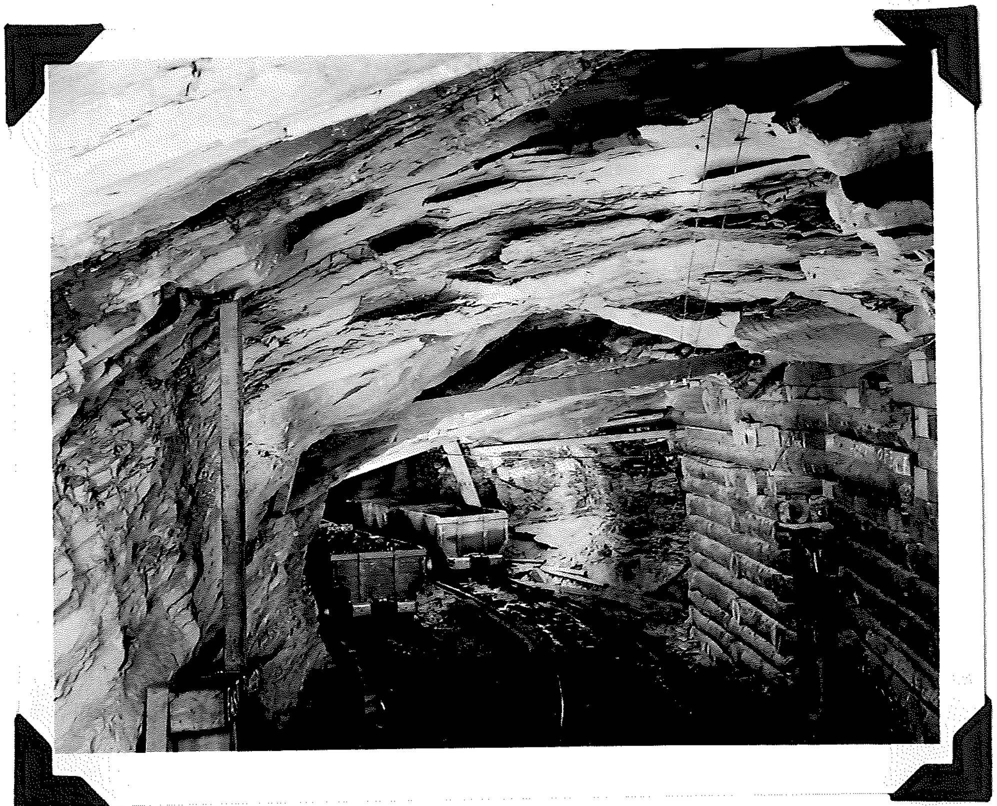


Plate XI. Turnway off a main slope into an entry parting. Loaded cars are wet down by high pressure sprays before hoisting.

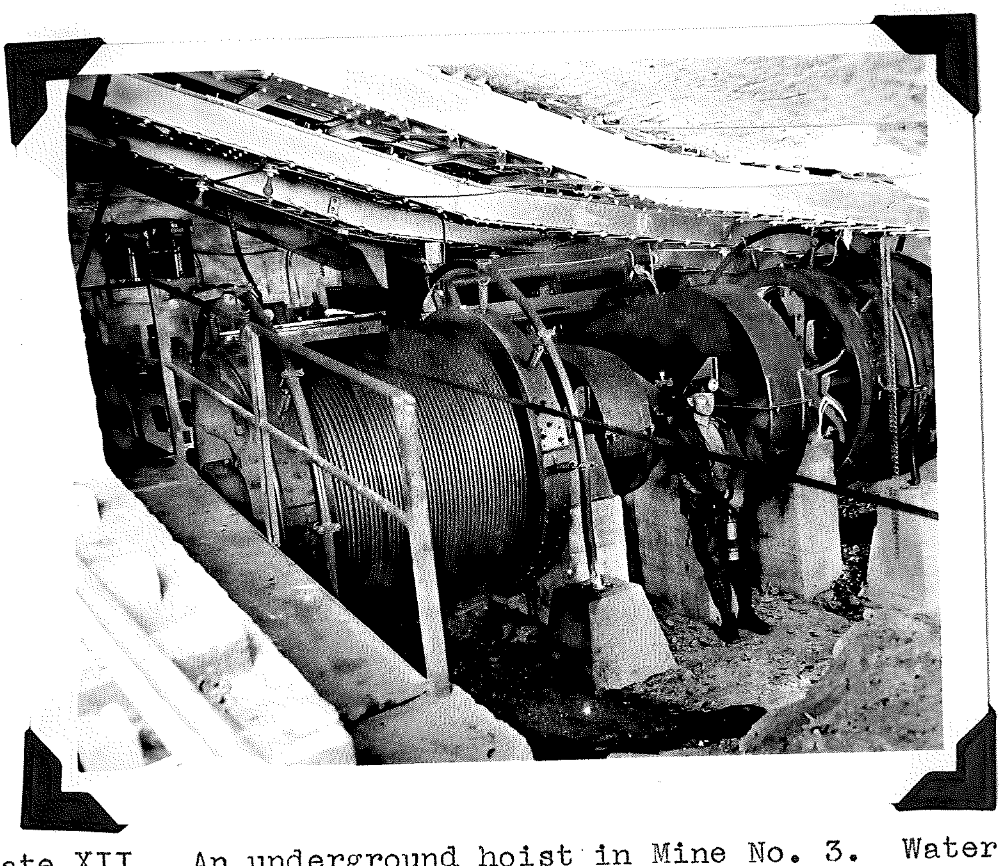


Plate XII. An underground hoist in Mine No. 3. Water rheostats, dynamic braking, and hydraulic clutchs characterize this home-built hoist.

one rope only, but greater safety and speed in getting men in and out of the mine were realized by balanced hoisting. Consequently, two trips are now used in counter-balance.

At Mine 9 a double-drum Allis-Chalmers is used for the main hoist, with much the same characteristics and set-up as at No. 5. A 600-hp motor, producing a rope speed of 1325 fpm is equipped with dynamic braking control similar to that used at Mine 5. The entire main haulage set-up at Mine 5 was copied and improved upon in the No. 9 installation, because conditions were much the same, except for a shorter haul. The ropes have been the same, being of 1-1/4 in. Lang-lay plow-steel, with the exception of a new rope, now installed on the left or west-side drum, which is made by Leschen and is of 1-1/4 in. Lang-lay patented plow steel, with flattened strand, and preformed, internally lubricated, hemp centers. The average grade on the No. 9 slope is 36°.

In all cases on main haulage ropes, Lang-lay is used in preference to regular lay. Tests made using a regular lay rope on one drum and a Lang-lay rope on the other showed that the Lang-lay would generally pull about twice the tonnage. Great care has to be used in installing these ropes, for the Lang-lay has a tendency to be wild, and wants to kink or "birdcage". After a few days of hoisting the rope stretches out, and this unruliness disappears. The patented flattened-strand preformed rope has proved to be better on first installation, because it is easy to handle, but as yet no tonnage records are available to ascertain the advisability of paying the extra premium cost.

In underground hoisting, two large hoists and many smaller hoists are used. The larger units are a 500-hp, short-wound, d-c hoist at No. 5 Dome Incline, and a double-drum 300-hp hoist located on the anticlinal flank in mine No. 3. This latter hoist is a revolutionary one in that it was designed and built by the Northwestern Improvement Company to haul coal under specific requirements. One drum was to run a 1-in. rope on a 9^{o}, 1200-ft slope, at 1,000 fpm, while the other drum was to hoist on a 600-ft, 22^{o} slope at right angles to the first, by a 1-1/4 in. rope at 500 fpm. The drums, geared two to one, and of different widths, work in counterbalance. Many smaller units, using both alternating and direct current, are scattered throughout the field and are generally homemade, with the exception of a few Denver and Vulcan types.

Automatic Hoists

Two unique, automatic man hoists are in use on the No. 5 airway slope and the No. 3 river airway. These hoists are homemade, and incorporate features such as low rope speed of 300 fpm, automatic stopping at top or bottom, overspeed and overwind devices, provision to stop the hoist in event of derailment, and to start and stop it at any point in its hoisting or lowering cycle through the use of bell wires, and low voltage on the bell wires so as to allow its use in return

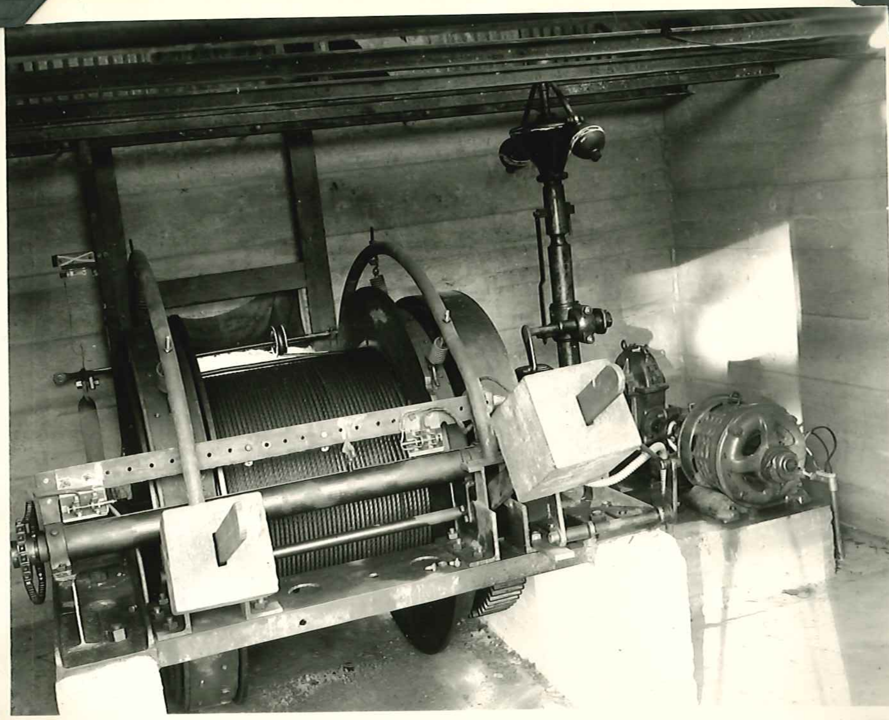


Plate XIII. Mine 3 automatic manway hoist. These automatic hoists are started or stopped by merely crossing the proper slope wires.

Plate XIV. Mine 3 automatic and gravity outer haulage. Loaded trips and empty trips are lifted to proper heights by the dolleys.

airways. No attendant is necessary, and operation is secured at any time, day or night, by mere crossing of the middle and outside bell wires in the direction in which travel is desired. Three bell wires are used, the middle wire being common to both directions. The hoist may be stopped at any point while in motion by a mere crossing of the opposite set of wires from those used in its starting. Then it can be set in motion again by crossing of the starting wires.

In the deep and hard travelling of such mines, automatic hoists of this type save much time and labor; also, they promote safety, inasmuch as the men do not have to ride coal trips.

Entry Haulage

All entry haulage is done by 5-ton haulage motors. Three types of trolley motors are in general use: Jeffrey, Westinghouse, and General Electric. Some old storage-battery motors have been converted into permanent 250 d-c series motors. Most of the motors are of the 500-volt d-c type, but, for safety, only 250-volt trolley lines are installed. The careful attention paid to grading and alignment of haulageways has allowed the company to operate these motors on the lower voltages. By the two-room retreat system of mining, the trolley wires are dead-ended past the first working room on the entry, thereby preventing any motor ignitions of gas or dust that might (inconceivably, under perfect working of the ventilation system) be pushed down from the rooms or pillars.

Haulage under conveyor loading is a simple mine operation, but great speed is required to keep the men supplied with empty cars. Two trips of uncoupled cars are pushed in ahead of the motor up under two pairs of conveyors. The four conveyors are loading from two retreating pillars and from two advancing rooms in every entry. The trips of eight cars each are stopped with the near end under the first or outside conveyor of each pair. The motor alone is dropped outside the length of a trip, so that the conveyorman of a pair of conveyors loading together needs only to remove a sprag from under a car wheel to let the loaded cars run from under the loading spouts by gravity.

When the cars have been fully loaded, the trolley motor couples onto them and pulls them out to a main-entry parting. The motor parks them on the high side, switches itself onto the lower track, and pushes empty cars back to the loading points.

When inclines and slopes are driven, small hoists bring the coal up to partings, where motors take the trips out to the main slopes.

Before the concentrated mining system was introduced, as many as 20 or 25 workings, rooms, and pillars were needed to supply the same amount of coal as is now secured from the 4 conveyors. Double-track rooms were required on the low dips; loaded cars coming down pulled the empty cars up by use of wire rope and a "bull" wheel. The speed of the cars was controlled by a wooden tie pressing the rope against the wheel, but sometimes the cars would get out of control, and before the miner could get away from the wheel, the empty car would pull into it.

The former advancing system of mining opened up so much ground that the haulageway bottoms heaved, causing costly track brushing. Ventilating drop sheets between all the room necks caused very inefficient ventilation. In the rooms, breakage of ropes and defective blocking of cars caused runaways that knocked props out, with consequent roof falls. At the end of the shift, miners would have to drop cars back 50 ft from the faces, to avoid squeezing and caving ground. The next day they would have to push the car back up to the working face, to hook it to the rope. This was a dangerous practice, but it was compulsory.

The chute system on the steep inclinations has not changed much in mining principle, except that now the coal loading is concentrated. A few large chutes up to the panel rooms have eliminated the former numerous vertical chute rooms. Ventilation and haulage have greatly benefited by the mechanized mining system.

Automatic Gravity Haulage

The mines, other than No. 3, have the loaded trips run up out of the slope and then drop back into the tipples. To get away from a quarter of a mile of rope haulage and to secure automatic gravity haulage, Mine No. 3 has driven two oppositely graded tunnels for that purpose. The reinforced concrete tunnels, 350 and 320 ft respectively, were driven on a grade of 3/4 of 1 per cent from the tipple to a large underground parting. Loaded trips hoisted from the workings are released at the parting, and are run by gravity to a pit at the tipple, where an automatic-dolley haul pulls an 18-car trip into the breaker. The empty cars released by the outside plant run back into another pit, where a similar dolley-car haul raises to sufficient gravity elevation a string of cars, up to a maximum of 18, which run back to the underground parting.

Running Gear

Installations of cast-iron running gear such as rollers, bull-wheels, and jitneys that are all cast in the local foundry, are common. Larger and much-used bull wheels are manganese-steel lined and, of late, rubber lined. Rubber-lined rollers are under experimentation on the two electric-hoist slopes and are proving very satisfactory. The wear on them is non-appreciable, as is the wear on haulage ropes from the non-abrasive rollers. The rubber-coated running gear did not stand up on the slope of Mine 3, because of the great rope speed used there. If the rope left the running gear for a second at the 2250 fpm hoisting, it would shred the rubber when it landed on the slower running rollers or wheels.

Coal Origin Numbers

Each district in a mine has a definite serial number, and all loaded trips sent from a particular district are marked accordingly. The tipple, on receiving the coal cars, credits that district with the tonnage weights. The results from district, and the mine total, are submitted by the outside foreman daily to the foreman of the mine.

VENTILATION

Types and Capacities of Fans

All fans of the Northwestern Improvement Company mines are centrifugals, equipped with Robinson short concave blades. All fans exhaust on the counter slopes, with the main mine slopes as the intakes. The reversing machanism and the doors of every fan are built in the setting. All fans are double-inlet except one.

The company uses centrifugal-type fans in preference to those of the propeller type, as the necessary air pressure can be secured at slower fan speed. Less bearing trouble, less attendance, and smaller prospect of fan shutdowns are secured by having no fast fan machinery.

Plate XV. Mine No. 3 river tunnel fan.

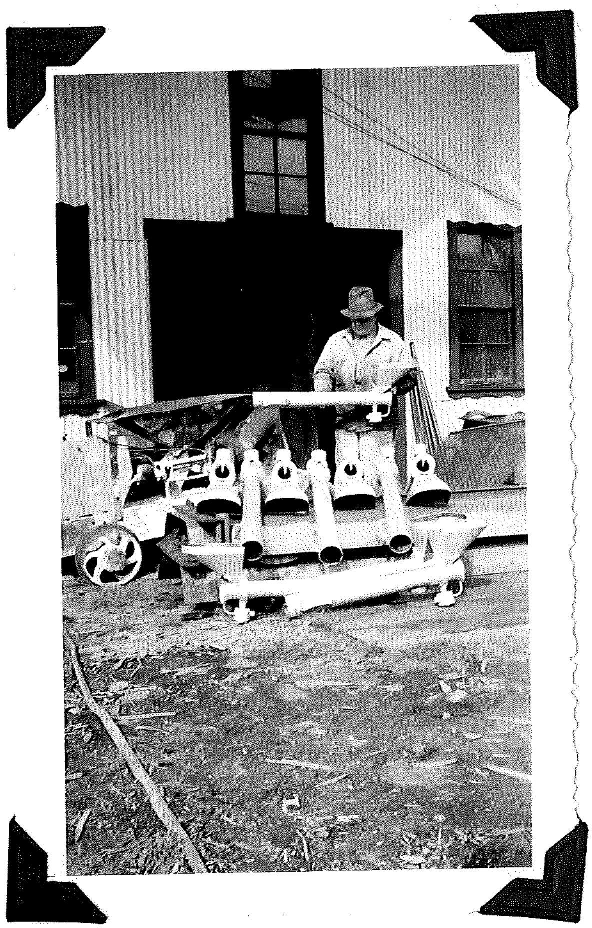


Plate XVI. Portable air rock dusters and one track rock duster.

The three mines utilize five fans: four of the Sirocco type and one Jeffrey. All settings are of reinforced concrete, with steel Evase stacks, and with double oiling systems.

DATA ON FANS

Mine Location	Type	Inlet	Horse-power used	Wheel Size	Revolutions per Minute	Intake Reading	Water Gauge
Old No. 1	Sirocco	Single	25	4x8	80	65,000	1.2
No. 3 River Fan	Jeffrey	Double	40	6x12	140	78,480	1.6
No. 3 Big Seam	Sirocco	Double	50	6x12	110	49,920	1.9
No. 5	Sirocco	Double	40	7'6"x8	172	77,200	1.6
No. 9	Sirocco	Double	20	8x12	82	84,000	1.1

Ventilation System

The ventilation in all cases is of the split system, with the main haulageways as the intakes. Ascensional ventilation is utilized, with the higher-counter entry as the return airway for each district. The manways or main counter slopes at whose portals the main exhaust fans are located are the main returns. The mines are classed as gassy; hence an excess of air is pulled through to keep all methane percentages below 0.004 per cent in every working.

Crosscuts are driven every 60 feet, and all stoppings are concrete, although a few years ago some were built of brick. Overcasts are either of reinforced concrete or, in some cases, of sheet iron. Most of the overcasts are driven in rock, but, where headroom permits, sheet-metal over-casts are made in sections at the mine surface shops, and are transported to the particular spot in the mines where they are to be used.

Air at the working faces is directed by brattice-lines around the few working places on each entry. The retreat system of mining allows fresh air to traverse the haulageways directly, then pass through the working places on the return, so that gases and powder smoke are taken away from the men. In no case does return air pass through haulageways. Few turnings, little chance for leakage, and shortcuts, give the fans the remarkable water-gauge readings exhibited on the previous page.

Natural Air Changes and Gas Data

Uphill lift of return air by increased temperature and consequent volume expansion aids the exhausting system of mine ventilation. To secure maximum advantage of the ascensional air aids, the return portals are, in all cases, lower in elevation than the intake portals. Seasonal moisture evaporation and deposition does not show up greatly in effects, but it is one of the factors concerned in the percentages of rock dust required to neutralize coal-dust collections.

Among the common gases found in the mines are methane, which is generated in large quantities. The safety engineer examines all entry air, and returns frequently with a portable methane detector to determine the percentage of methane. If it is over 0.004 per cent, he increases the amount of air on that particular split. The fire-bosses inspect all working places daily with safety lamps, for gas indications.

Barometric pressure relative to old workings is of little consequence in the Northwestern Improvement Company mines. The old No. 1 fan, bleeds off all the gases created in old workings not already sealed off.

DRAINAGE

During the long period in mining operations in the Roslyn field prior to 1925, pumping had not been such a problem, mainly because of the fact that most of the tonnage had been taken from above or slightly below water level. With the end of water-level mining in sight, more attention was paid to pumping and sealing of the surface water.

Unfortunately, in most of the mines, rooms had been driven close to the surface, and pillars had been pulled. Efforts had been made to keep a barrier at water level to run off surface water, but, in many cases, airways, haulageways and even regular rooms had been driven in such places as to cut through this level. As a result, surface water seeped in at various points and found its way to lower levels, from which it had to be pumped. This condition prevailed throughout the field. In order to avoid confusion through devoting too much attention to small details that would be better left to a separate report, the situation will be described as at Mine 5 alone.

Detailed Mine 5 Pumping System

Until about 1926 four pumps were stationed at the first east and west entries, two at the third east, two at the eighth east, one at the ninth east, and one at the tenth east, at a depth of 99.5 ft, which at that time was the bottom of the mine. These pumps were mainly of the triplex plumger type, except for some single and two-stage belt-driven pumps at the upper points. Water was generally relayed from one pumping point to another, and power was in nearly all cases 500 volts, d-c.

Water came into the first east entry through rooms caved to the surface in the revine below the former boiler house. It had to be pumped out of the first east, and at times came in such volume that it ran down to the third-east-entry pump. Dams were built in the first east main and back entries, raising the water 56 ft, from which elevation it runs out through the east end of the entry into a canyon. A dam was also built on the first west entry parting, raising the water 5 ft. From this point it flows out through a former haulage tunnel. Approximately 26,000,000 gallons of water are stored in the first east entry. Provision is made at the eighth east and seventh west entries for catching this water should anything unlooked for happen which would turn it loose on the lower workings. In this way, it would also be prevented from reaching the present workings.

On the present double-track hoisting slope driven in rock, fissures in the rock liberated a considerable amount of water in the form of drippers. These were annoying in cold weather, because upon freezing they would cover the tracks, and the ice would have to be chopped away. For years a fan was kept at the mouth of the former airway, adjacent to the old slope opening; in cold weather this fan was started, forcing air down the old slope in an amount to exceed the return volume. At the junction of the old slope and the new, this air would form a sort of split, and several thousand cubic feet would go up the new slope, changing it from an intake to a return airway, even though the air was fresh and had not passed any of the regular working tunnels. Being warm, it kept the slope free of ice: This method worked satisfactorily except that it required attendance upon the fan and meant that the blocks of coal protecting the old slope had to be kept intact, and thus tied up. Accordingly, a new method was tried which has proved to be adequate, so that now the water is drained off before it has a chance to be exposed to the air and to become ice.

The concrete portal was extended 300 ft, to stop the worst of the drippers close to the surface. From a point slightly above the end of the concrete down to where a crosscut had been driven between the slope and the airway, a ditch at least 4 ft deep was dug between the two tracks. In it were laid 4-in. clay tiles, the unsealed bell ends of each pointing up the hill. Porous material was laid over the tile, and the entire ditch was covered. This ditch cut through the fissures on the bottom, causing the water to seep into the tile pipe at the joints, and this water was diverted directly into the return airway at the crosscut. Cutting the fissures in this manner has reduced the drippers to a negligible amount; now very little trouble is experienced with freezing, although two cold winters have passed since the tile was laid. Provisions are now being made to extract the old slope blocks.

One centrifugal pump was installed at the eighth level east, of 1507.4-ft elevation, and this soon took the place of all the pumps above that point. It is a No. 5 H.M.T. 4-stage Cameron centrifugal pump, rated at 600 gpm at 665 ft of head, and directly connected to a class M.T.P. 250 hp, 2200-volt, three-phase a-c, 1800-rpm General Electric Motor, with drum controller and resistance for 25-percent operation. This type of motor control was specified because when the pump was in continuous service for a year and a half in dewatering an adjacent mine, enough pressure was put on the suction to take the water out satisfactorily with this slower speed of operation. The pumps purchased later are of the same type, except that they are powered with motors of the squirrel-cage induction type.

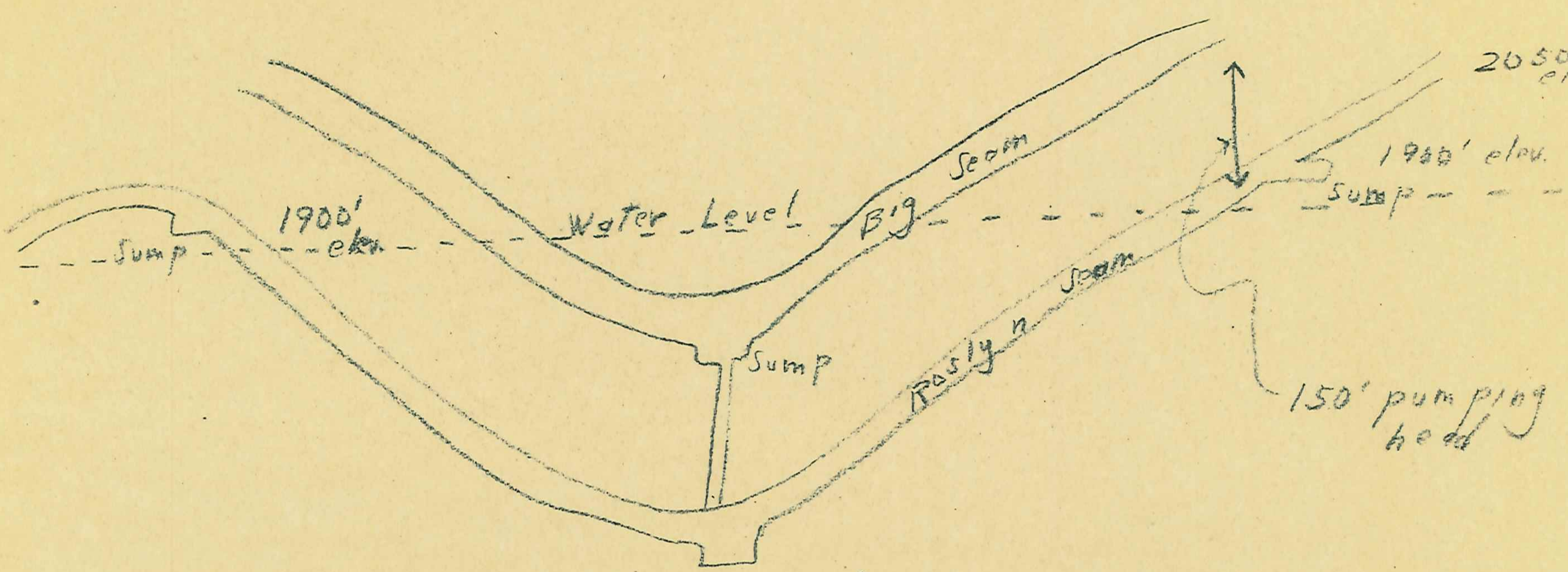
In the installation at the eighth east entry, 1507.4 ft, the head on the pump is considerably less than that rated; as a result, the measured discharge is 850 gpm. In April, 1932, an Allis Chalmers size-4, 5-stage 400-gpm pump at 700-ft of head, directly connected to an Allis Chalmers 150-hp, 2200-volt motor, was installed at the eighth east, 1507.4 ft, to act for standby service and in high-water periods. In measured discharge it was found to deliver 600 gpm, or 1200 gpm when pumping in the same discharge line with the Cameron. In nearly all cases, pipe lines are 6 in. in diameter and are laid in the manways, with the exception of the discharge line to the surface, which is laid in the return airway.

A Cameron pump of similar capacity is situated between the tenth west, 999.5 ft, and the eleventh west entries. Installation is now being made of a triplex upright pump at the lowest present point in the mine, namely the thirteenth east entry, 528.3 ft, to take the place of the present auxiliary plunger pumps, which are Aldriches of 300 and 100 gpm capacity. This new pump will work against a head of 500 ft and will deliver approximately 150 gpm.

As is interesting to note, in the year 1939 at Mine 5, 65,725,000 gal of water was pumped. It required 5.75 kwhr per thousand gallons pumped against an average head of 1150 ft. The total was 377,919 kwhr for the year. At the present time in this mine, approximately 4.5 tons of water are pumped for every ton of coal mined, although in the spring of wet years,

Figure 12

Mine 3 Pressure Sump



Pressure Sump
and
1000 gal/min. at 700' head Ingersoll-
Rand Pump

as much as seven and eight tons of water have been pumped for every ton of coal hoisted.

Mine 3 Pressure Sump and Balanced Synclinal Columns

The pumping set-up at Mine 9 is similar to that of Mine 5, but Mine 3 has taken advantage of the water pressure from its Big Seam and from its Roslyn Seam synclinal-anticlinal drainage. In the sketch of the Mine 3 (1) pumping system, may be seen the course by which the water from the mine workings on the flanks drains into a common sump. Water created by the workings in the Big seam that overlies the Roslyn seam at an average of 250 ft drains through a water hole into the common pressure sump.

By the laws of gravitation, the water in the synclinal pipe lines reaches common water levels at a maximum of 1900 ft of elevation. The drainage outlet of the mine is at 2050 ft of elevation, necessitating a pumping head against only 150 ft. With intricate valves, many automatic, a 1000-gpm Ingersoll-Rand pump of 700-ft head is situated at the common pressure sump.

No. 3 is a mine that was first opened when centrifugal pumps were only in the experimental stages. As the main

1. The No. 3 mine is the only mine of the three that has direct openings to the surface from both synclinal flanks. Often the western flank of the syncline is spoken of as the anticlinal flank. The left or west flank of the anticline is undeveloped at present, but it is being prospected by the Pioneer entry of Mine No. 3. This same mine is the only Northwestern Improvement Company mine with present and past operations in the Big seam.

slopes down the syncline in the Roslyn and Big seams were reached, finally, 6,000 ft before coming to the basin, 14 pumps were required altogether. Today, with the balanced and correlated drainage system, one pump operates in place of the former fourteen.

SAFETY MEASURES

ACCIDENT CONTROL

Company Rules

Every new employee, at the time he is given his starting work slip, is given as well as small pamphlet of safety rules prepared by the company after its compilation and analysis of all accidents that have occurred in the Roslyn field. It employs a full-time safety engineer whose duties are to see that the state mining laws and the company rules and regulations are complied with. He is responsible also for the proper assembly and condition of all equipment that has been approved by the United States Bureau of Mines.

A three-fold checking system is utilized at the mines for safety control of the underground employees. Before starting their shifts, all employees must pass before the haulage foreman in the morning, or before his appointed assistant on the afternoon shift, and must give him their check numbers. Before entering the mine, each is required to take a metal tag stamped with his own check number, and at the end of the shift the tag has to be replaced on the check board kept at the mine office for that purpose. This board is examined by the mine foreman or his assistant at the completion of each shift. In addition, the unit foreman of each district must see that all his workmen are accounted for before leaving his district at the end of the shift.

The company operates a central first-aid and mine-rescue station which is equipped with eleven McCaa oxygen-breathing apparatus, one H-H-inhalator, and a sufficient supply of materials. Approximately two hundred men in the mines have been trained in mine-rescue work. Teams of seven men selected from each mine are retrained once every six months.

All new employees are trained in first aid once a year, and all former employees have retraining every two years. Since this first-aid training has been in effect, in addition to ensuring proper care of an injured workman, after an accident, it has reduced the severity rate to a considerable extent.

Permissible Powder and Electric Blasting Caps

Various types of permissible powder are used for blasting the coal and shooting up the bottom rock for track grading in all development work. Du Pont Monobel powder of 60-percent strength is commonly used, and powder in all cases is exploded by Atlas waterproof electric blasting caps. No delay electric igniters are used anywhere in the mines, and all detonators are equipped with shunts to prevent accidental ignitions.

Considerable difficulty was experienced in using 1-1/4 in.

by 8 in. sticks of permissible explosives, owing to the fact that the average shot required 3 sticks of explosives per hole, so that at times while the hole was being tamped, coal would get between the sticks of powder and so prevent some of the explosives from firing. The unexploded cartridges would then be loaded out with the coal, creating a hazard and also preventing the other shots from doing effective work. To insure against improper tamping, a single 1-1/4 in. by 24 in. cartridge, in place of the three shorter ones, is placed in a drilled hole. All shots are fired by the unit foremen, who hold certificates of competency.

The powder consumption has been reduced considerably since mechanization. Under the hand-mining method, 1-1/2 tons of coal were mined per pound of powder used, as compared to 8 tons when the coal has been sheared or undercut.

The changing of the old hand-mining methods to mechanized mining has had its effect upon safety records. The safety and efficiency of the mines has been immeasurably improved, and mechanization in comparison with hand mining can be truly considered successful only if it reduces accident rates on a man-hour exposure basis.[1]

Mechanization and Concentrated Control

The use of conveyors has practically eliminated the room accidents formerly prevalent, by taking mine cars up to the room faces. Through undercutting of the coal, the dangerous practice of solid shooting is overcome, and eye injuries that used to occur with pick mining have been practically eliminated. The replacing of all open-type electrical equipment with permissible equipment not only has decreased maintenance costs but has removed a dangerous hazard from explosions. The abolition of all black powder, which has been replaced by permissible explosives fired electrically and systematically, and also the abolition of open lights regardless of the non-presence of gas, have also increased the safety of the mines.

Supervision is better and more efficient under mechanization. The system requires a unit foreman to every 2 or 4 working places; he inspects the working places constantly. He goes in with the crew, and comes out with the crew, and he is responsible for all production, safety, ventilation, and maintenance of his working district. The psychological aspects of safety are better secured under the grouping of workers, and with the day-scale system of wages.

FIGURE 13

Comparative Fatal Accident Rates at the Fully Mechanized Mine No. 3 and the Hand-mining Mine No. 7, for the years 1930-1932.

Year	Tonnage Mined (net tons)		Man-Days (8 hr.)		Tons Per life Lost		Man-Days Per life Lost	
	No. 3 (Mech.)	No. 7 (Hand)	No. 3 (Mech.)	No. 7 (Hand)	No. 3 (Mech.)	No. 7 (Hand)	No. 3 (Mech.)	No. 7 (Hand)
1930......	243,796	397,854	60,350	95,429	No fatals	397,854	No fatals	95,429
1931......	209,571	293,062	50,740	68,059	209,571	97,687	50,740	22,686
1932......	162,101	244,541	38,533	57,273	162,101	122,270	38,533	28,637
1930-32...	615,468	935,457	149,623	220,761	307,734	155,909	74,811	36,793

COAL DUST CONTROL AND ELECTRICAL EQUIPMENT TESTING

Rock Dusting

Rock dusting is done extensively in all the mines. Each mine has a track-mounted high-pressure rock duster, and a number of portable hand dusters. Slopes, haulageways, and airways are gone over once every 6 months with track-mounted dusters, and in all development work a portable modified Lamb Air Foil is used to keep the rock dust within a few feet of the working faces at all times.

The safety engineer examines the haulageway rock-dust coatings on his inspections of the mine, and if more than 35 per cent of coal is found in the mixture, he requests immediate rock dusting of the area.

Water Sprinkling

Great care is taken to wet down the coal dust at its source by hose sprinkling of the cutting bar of the mining machine during the cutting process. The miners spray the coal surfaces before and after blasting it loose from the mining face. All main-entry partings at the slopes of the mines are equipped with high-pressure sprays which wet down the tops of loaded cars before they ascend the slope against the intake air.

Guard of Vagrant Electric Currents

With the great amount of electrical equipment in the mines, much concern is spent in bonding rails for current returns. Pipe lines are commonly used as machinery grounds. If the bonding were neglected, electricity would leak from the pipes and rails into the ground, thus causing vagrant currents which might charge conveyor lines or explode detonators. If current leaks off, disintegration of the metal then takes place.

Company Permissible Equipment Testing Chamber

Every motor and starting box of electrical equipment, as well as each safety lamp, is tested by the safety engineer before going into the mines. The machines or compartments that are to be tested are assembled at the shop, and are built according to the Bureau of Mines specifications. The testing chamber, made of reinforced concrete, has a volume of about 200 cu ft. It has two observation windows; its six pressure-release openings on the top and five openings on the door are covered with water-proof roofing paper. Their purpose is to release the pressure in case of an explosion in the testing chamber.

In each compartment to be tested are two half-inch holes. One is used for the spark plug, which ignites the gas; the other indicates the pressure developed by the explosion. The two 1-1/2 in. holes are for spring valves, which admit the explosive mixtures into the compartment. The gas is forced in by a circulating fan.

The equipment is then placed in the testing chamber and is piped to the gas-circulating system so that all the compartments can be filled with a mixture of gas and air. The gas is admitted through a meter into the testing chamber; where it is circulated with a fan. The spark plugs are installed at different points, so that the ignition will be under the operator's control. An indicator records the pressure developed by the explosion in the compartment under test. When spark plug and pressure indicator have been connected, the testing chamber is closed, and an explosive mixture of gas and air is made by adding the proper quantity of gas and thoroughly mixing it with the fan. The gas admitted to produce the explosive mixtures varies from 2-1/4 per cent to 5. The maximum explosive point is about 3.75. When the explosive mixture has been then drawn into the compartment under test, this compartment is isolated from the piping and testing chamber by closure of the spring valves.

Watchers are stationed at the observation windows, and the explosive mixture within the compartment is ignited. Observations are then recorded. A second test is generally made with the same gas mixture and under the same conditions, the indicator drum being reset from the outside of the chamber. Then the chamber is opened, and the gas mixture is removed by the circulating system. The operator enters the chamber, makes his inspection, removes the indicator card, puts on a new one, and prepares the equipment for the next test.

If the equipment is to meet the test requirements, the gas mixture surrounding it must not be ignited, flames must not be discharged from any point, nor must excessive pressure develop in any of the compartments. Each compartment is tested ten times.

TROPHY WINNINGS

In 1926 at the International Mine Safety and Mine Rescue Contests held at Kansas City, Missouri, the company's first-aid and mine rescue teams were the international winners in both events. In 1927 they won the two events again at the meet held in Butte, Montana. Recent years have seen no international competition.

The Northwestern Improvement Company, was recently awarded a Joseph A. Holmes certificate for having operated from January 10, 1933, to January 1, 1936, with an average of 414 employees working 1,554,787 manhours and producing 808,091 tons of coal, without a single fatality. On September 1, 1936, 1,172,059 tons had been produced, and 2,141,814 manhours of labor had been performed, again without fatality.[1]

MAINTENANCE

CENTRAL SHOP AND MINE MAINTENANCE SHOPS

At the north end of Pennsylvania Avenue in Roslyn are brick, concrete, and galvanized iron buildings which include the main shop, the maintenance gang's shop, the warehouse, and the permissible-equipment testing chamber.

From the machine shop comes nearly every piece of machinery used in the company's mines. By assembling machines especially adopted for local use, the shop has repaid its investment many times over in costs, fewer injuries, and work for local employees. Members of the company organization have invented many of the adaptations and much of the machinery built.

Few mine shops have such facilities for reconditioning worn-out machines. The shop also standardizes its own constructions, to ensure compliance with state requirements for "permissible mine equipment".

Starting as a small blacksmith shop in 1886, the shop has grown to an organization employing 22 men. The departments are six: welding shop, machine shop for making parts, construction shop for assembling machines, blacksmith shop, carpenter shop, and electric shop.

The machine shop is equipped with four lathes, sharper, metal planer, shirring press for clipping and punching iron, two drill presses, hydraulic press, and bolt-cutting and threading machine.

A small shop is located at each mine for general heavy maintenance work. All welding and repairs of conveyor pan lines are done in them. Haulage motors are overhauled at pits built into each shop. General blacksmithing work is done daily on drills and picks. In the smaller shops, cutting-machine bits are sharpened, tempered, and tungsten-tipped. Each is equipped with acetylene and electric welding apparatus, cutting-machine-bit sharpeners, electric and post drills, emery grinding wheels, and a lath.

FOUNDRY

The local foundry casts most of the running gear, conveyor bearings, and shell ends for the permissible motors. Special orders are made up, such as hoist-drum ends and machine foundations.

WAREHOUSES

The central warehouse contains great quantities of mine supplies that are trucked to the mine on call. Quantities of every kind of mine equipment are kept on hand, so that no delays will be due to lack of repairs or of tools. False-economy policies are not tolerated, and supplies are sent from here not only to the small mine shops, but into the mines at storage places on the entries.

The old brick power plant now serves as a storage center for the better unused machinery. Some smaller older buildings enclose old machinery and parts.

WASH-HOUSES

For years, change-houses have been standard outside equipment of the mines and of the main shop. These wash-houses are of three-compartment construction: the shower room divides the clean change from the mine clothes' change. Miners pay one dollar per month for the upkeep of these buildings.

TELEPHONE SYSTEM

The company's whole organization in the Roslyn-Cle Elum field is connected by its own telephone system. All departments, mines, and company officials are connected to the exchange in the main office. Each mine in turn has direct wires to all of its departments, to central points inside the mines, and to the residences of the mine superintendents and the mine "fire bosses".

Plate XVII. Mine 9 tipple.

Plate XVIII. Mine 9 brick washhouse.

ENGINEERING

DEVELOPMENT FOR FUTURE PRODUCTION

Entries are turned off to make about a 400-ft lift for rooms. Because of synclinal and anticlinal structure in deeper workings, often slopes and inclines must be driven many hundred feet before turning off a productive entry. Narrow work is driven several years ahead, so as to furnish production beyond normal demand, should occasion occur, and to provide against difficulties that may develop, such as a mine closed on account of fire, flood, or faults.

DIAMOND-DRILL PROSPECTING

To date 103 diamond-drill holes have been put down by the company. The last series were drilled in 1926 and 1927 as the preliminary plans for the proposed mine No. 9. From the drill records, structure maps were made, and the engineers calculated the proposed dip of the rock tunnels which would conform with the average dip of the Roslyn coal seam. Owing to the anticlinal dome structure previously mentioned, and to uncertainty as to strata disturbances where the drill holes struck the coal seam, the company officials drilled along the line of the proposed slope. The drill hit the coal seam exactly as had been calculated.

The first slope sunk was the proposed counter slope or air-return slope. Crosscuts were driven from it over to the slanted drill hole, and the hole was found to act as a very efficient return airway. When the coal seam was opened up, the main slope was driven from the inside out along this drill hole, keeping the slope in nearly perfect alignment.

SURVEYING AND MAPS

The Northwestern Improvement Company goes to every possible extreme for accurate surveys. A system called continued azimuth surveying is used, and every station is coordinated and plotted by the same method on the regular maps. The egg-shell-base maps and tracings are kept in the Seattle office in fireproof vaults.

Surveys throughout the Roslyn field are kept in duplicate form. The original field notes are copied in Seattle field books, forming a duplicate system, and all calculations are independently figured in Seattle and checked with the Roslyn figures to eliminate error.

Blueprints of individual mines on a hundred-foot scale are placed in all mine foremen's offices every three months. The maps are continually consulted for intelligent operation of advancing work, connections, and ventilation problems. They are brought up to date every three months, but any special feature, such as progress through a faulted area, is posted in between times, to ensure a timely knowledge of the progress.

The largest map in the United States, according to the opinion of visiting United States Bureau of Mines officials, is the large blueprint which papers an entire wall and part of the ceiling in the office of the general superintendent of mines, in Roslyn. Drawn on a scale of 100 ft to the inch, it charts an area seven miles long--from east of Cle Elum to west of Ronald--and more than three and one-half miles wide--from the north ridge of the valley to past the Yakima river.

The map has taken fifty-three years to reach its present size: it could develop only with the mines. Now it has covered a 30-ft wall and has started to extend onto both end walls and the ceiling. It must be rolled at the bottom to keep from stretching along the floor.

Numerous cross-sections, profiles, bore-hole maps, logs of bore holes, and insurance maps are in the offices. All mine maps showing outside surface features, contours, building, and power lines are in the engineering office.

UNIFORMITY OF ROOMS AND PILLARS ADJUSTED TO MINING CONDITIONS AND TO ROOF CHARACTER AND PRESSURE

Rooms are all driven on sights placed at predetermined intervals dependent on the particular mining conditions of the district. The width of the rooms and pillars in the mines, and in their different districts, is not uniform, because of the varying weights of overburden, synclinal and anticlinal basins and ridges, thickness of fireclay underlying the coal seam, type of mining method, and speed of coal extraction. Always, the desire is to distribute the weight of overburden uniformly over workings to avoid bringing on squeezes, bumps, and fireclay expansion, and to allow maximum coal recovery. Uniform caving lines are planned and are watched on pillar extractions, and the full retreat system is an adjunct to nice pillar-caving lines and to full coal recovery.

BARRIERS FOR WATER SEALS AND FOR SAFETY

Barrier pillars are left as high as 250 ft between different mines and between old and new workings. In certain places in the synclines where the strata are disturbed and cracked, water has been known to traverse over 1500 ft, - Roslyn Cascade water seeping into Mine 3 and water from the old Independent, seeping into No. 7. The slow seepage of such water adds to the amount already created by the workings of each mine. For this reason, the southermost mine in the field and also the lowest in elevation, Mine No. 5, pumps out more water than any other.

IMPORTANCE OF GRADES AND ALIGNMENT ON HAULAGE

An effort is made to maintain track grades at 3/4 of

1 per cent in favor of the loads. A grade board 7 ft long, with bubble level, is used for that purpose in all entry driving, and the district supervisor is held accountable. The importance of grades and alignment in the 4 ft 6 in. Roslyn seam is shown in the amount of rock brushing required on haulage ways. All haulage ways require a certain amount of bottom brushing, and in the steeply dipping area an average of 3 ft of rock is taken up. With the increased speed of advancement obtained by mechanization, the alignment has to be checked regularly and often.

To permit greater haulage speed with less danger of wear and tear and wrecks, the main slopes and some of the main entry haulage ways are lined with 60-lb steel rails. The rest of the entries are a 40-lb and some 30-lb steel rails.

MANAGEMENT

DEPARTMENT SPECIALIZATION AND RESPONSIBILITY

The general superintendent receives a daily cost sheet which has been made up by the main office. Every phase of operation is briefed, under Supplies Used, Results Secured, and Costs of Operation. Bright spots and sore ones are immediately seen and judged. Monthly and yearly costs are detailed into different operating phases. All new construction jobs, shop work, and special operating features are given a serial number by which all supplies, wages, and maintenance costs for each operating phase can be correctly charged and itemized.

Daily reports, besides those from the mines, the washer, and the main shop, are turned in from the following operating departments.

a. The maintenance crew, which travels around from mine to mine, doing all the special repair work that is necessary to keep the mines functioning properly. The men are on call at all times, and are always summoned in case of an emergency.

b. The electric utility gang, whose duty is to keep the power in the mines completely under control at all times. A shut-off of power for any length of time interrupts the ventilation in the mines.

c. The timber cutters, working in the woods around the mines, who supply the immense amount of rough lumber and timber which is required inside the mine. In some months the mines average nine board feet of lumber per ton of coal mined. The office force take care of all business connected with the mines, issue the pay checks, and report to the higher offices which are situated in Seattle and in St. Paul, Minnesota.

The Northwestern Improvement Company has all its departments inter-related on a coordinate basis rather than on the subordinate basis characteristic of many large organizations. Mine superintendents and mine departments order supplies from the central shop and warehouse, or call the repair and electrical crews for all needs except special needs without the undue loss of time and the "red-tape" of the subordinate-permission system. Requisitions for special orders must be given by the general superintendent.

PERSONNEL AND UNION RELATIONS

Wages, which are all for day work, are scaled, and work is classified, providing an incentive for skilled work and responsibility. Company officials are selected from the ranks, an old policy of the Northwestern Improvement Company which provides leaders trained to local standards and conditions.

The organization has been consistent in "Home help hired first". The above conditions make more wholesome communities.

The miners' national unions have been recognized for about thirty years. Wash-houses, doctors' and nurses' offices, and a local hospital, are supported by the employees, and the men have here a choice of their own doctors. The miners' families receive medical attention, the same as the miners themselves, in this employee medical association.

Employees of this company have always been community men. Some of the old-timers have been with the company since the very first years. The Northwestern Improvement Company did not hesitate to show its respect for its men, an unusual attitude for a coal company. It pioneered for the best conditions for its aged and for its disabled employees by providing a pension mine, the Townsend Mine previously mentioned. Old employees also hold watchman and minor repair jobs.

EMPLOYMENT, LABOR CLASSIFICATION, AND WAGES

The complete record of the employment is as follows:

	Men
Mine 3	256
Mine 5	214
Mine 9	184
Townsend Mine	50
Cleaning Plant	34
Prop Cutters	31
Maintenance Gang	30
Company Officials	25
Roslyn Shop	23
Office	9
Electric Utility	8
Dip Mine (House Coal)	5
Warehouse	2
	879

Inside labor classification and the wage scale are as follows:

	Per Day
District Foremen	$ 9.90 (1)
Fireboss	8.25 (1)
Haulage Foreman	8.00 (1)
Machine Runners	7.80
Duck Bill Operators	7.40
Machine Timbermen	7.00
Machine Loaders	7.00
Electricians	6.40
Sprinklers	6.40
Timbermen	6.40
Rope Riders	6.00
Hoistmen	6.00
Motormen	6.00
Helpers	5.70
Pumpman	5.70

(1) $9.20 per day plus 1/2 hour overtime. These foremen also work a number of idle days each month moving machinery. Fire bosses and haulage foremen work independently of the number of days the mine works.

COAL PREPARATION AND DISTRIBUTION

CENTRAL CLEANING PLANT

The site of the washer is about mid-way between the towns of Roslyn and Cle Elum, slightly below the tipple of Mine 5, and on a graded parting off the main Northern Pacific railway branch line. The location has favorable railroad grades, ample water supply from the pumping discharge of Mine 5, which averages about 175,000 gal per day, and an excellent refuse and waste-water disposal ground. The output of the mines is switched into the raw-coal yard, just above the plant and parallel to the main line of the Roslyn branch. A separate track capable of holding a full day's run--22 cars--is provided for the coal from each mine. These tracks converge into a single line leading over a track hopper at the upper end of the plant, then diverge into two parallel loading tracks running under the plant and beyond, to the cleaned-coal yard.

This plant combines wet-washing, dry (air) cleaning, and heat-drying. The raw-coal feed includes chunks up to 3 in. in size, and takes all the minus 3 in. material screened out of the run-of-mine at each tipple, plus the crushed picking table middlings, and, at times, all of the crushed lump.

It is dumped from the railroad cars into a 50-ton track hopper, equipped with two reciprocating feeders in the bottom that feed the coal onto a short cross-conveyor belt. This belt carries the coal out from under the hopper and discharges onto the main conveyor belt that delivers it to the top of the plant.

The 3 in. to 1-1/4 in. size goes directly to the No. 1 Vissac jig, the 1-1/4 in. to 3/4 in. size goes directly to Vissac jig No. 2. The minus 3/4 in. goes via bucket elevator and regulating feed chute onto a 4-ft by 8-ft Tyler screen. The oversize (3/4 in. to 5/16 in.) goes directly to the No. 3 Vissac jig, and the minus 5/16 in. size goes via screw-conveyor to an American Coal Cleaning table, type Y, Size BB.

The washed product from the first Vissac jig, together with the overflow wash water, passes directly onto a 4-ft by 20-ft rinsing, dewatering, and sizing shaker-screen. The oversize product of the top deck (3 in. to 1-5/8 in.), designated as Egg coal, goes either directly to railroad cars via shaker conveyor and belt loading-boom, or to the house coal bin via flight conveyor. It may go to a blending conveyor carrying one or more of the smaller sizes. The 1-5/8 in. to 3/4 in. product (Nut coal) is either added to the Egg coal, or loaded separately in the same manner as the latter. It may be added to the blending conveyor.

The washed product from the No. 2 Vissac jig, together with the overflow wash water, goes directly onto a 4-ft by 20-ft shaker-screen that rinses and dewaters the coal. The oversize product from this screen, 1-1/4 in. to 3/4 in., is also designated as Nut coal; it is either added to the Nut size from the No. 1 jig and loaded directly into railroad cars, or it is added to the blending conveyor. It may also go via flight conveyor to the surge hopper at the head of the Vissac dryer.

The washed product from Vissac jig No. 3, together with the overflow wash water goes to a separate rinsing and dewatering screen. The oversize product from this screen, 3/4 to 4 mm, is designated as Pea coal; it either goes directly to the railroad car via shaker conveyor and loading boom, or goes to the surge hopper at the head of the Vissac dryer, or via flight conveyor to the house coal bin.

The cleaned product (5/16 in. to 0 in.) from the air table goes via conveyor belt either directly to the railroad car, or to blending conveyor, where it is combined and loaded out with one or more of the coarser sizes.

The refuse products from Vissac jigs 1 and 2 are discharged directly into a tooth-roll crusher and broken down to a minus 1-1/2 in., to which is added the refuse from Vissac jig No. 3, thence they go via flume to the refuse rewash jig. The washed product from this jig goes directly, and with part of the overflow wash water, through a corrugated roll crusher onto a Deister table. This crusher reduces the material to about minus 1/2 in. Added to this material at this point and forming a part of the feed to the table is the refuse and middlings from the air-table.

The washed product from the Deister table, together with the wash water, goes directly to the sludge tank. This is a wooden tank 8 ft wide, 10 ft high, and 35 ft long, equipped with an endless drag conveyor for removing the solids at one end. Also added to this sludge tank is the degradation from the Vissac jigs and dewatering screens.

The solids, on being dragged out of the sludge tank, are discharged directly by the conveyor onto a 4-ft by 20-ft rinsing and dewatering screen. The oversize (1/2 in. to 1/2 mm) from this screen is elevated by bucket elevator to the surge bin at the head of the Vissac dryer. The undersize, together with the rinse water, is pumped out as waste to the settling pond.

As was stated above, either Nut or Pea coal may be run into the surge bin at the head of the Vissac dryer. As a matter of fact, some of either one or the other is always run into this hopper in order to assist drying of the sludge. Thus, the feed to the dryer is always a mixture of sludge (1/2 in. to 1/2 mm coal) and either pea or nut coal. This mixture is fed by a reciprocating feeder to the Vissac dryer at the rate of 50 or 60 tons per hour. The dried coal passes into a bucket elevator discharging onto a flight conveyor that brings it back to the steam coal loading chute, at which point it is blended with one or more of the undried sizes.

By use of the blending facilities and flexible loading arrangement of the plant, the following products, or combination of products, are thus readily made available for market.

1. Egg 3 in. to 1-5/8 in.
2. Egg-Nut 3 in. to 3/4 in.
3. Nut 1-5/8 in. to 3/4 in.
4. Nut-Pea 1-5/8 in. to 4 mm.
5. Pea 3/4 in. to 4 mm.
6. Buckwheat 5/16 in. to 0 in.
7. 3/4 in. Steam (5 plus 6)
8. 1-5/8 in Steam (3 plus 5 plus 6)
9. 3 in. Steam (1 plus 3 plus 5 plus 6)

About 6,000 gal per min of wash water is recirculated for washing the coal, and about 400 gal per min of fresh water is added to the system through sprays on the rinsing screens. The wash water is re-circulated by one 14 in. by 12 in. Worthington centrifugal pump equipped with stainless steel shaft and impeller, and one 8 in. by 8 in. rubber lined Hydroseal pump. The fresh water is delivered from the reservoir tank to screens by a Worthington 2 in. centrifugal pump. The waste water and slurry are discharged to the settling pond by one 8 in. DeLaval pump and one 3 in. rubber lined Hydroseal pump.

The ash content in the raw coal feed to the plant ranges from 17 to 22 per cent. The cleaned coal carries an average

Plate XIX. A few Townsend miners.

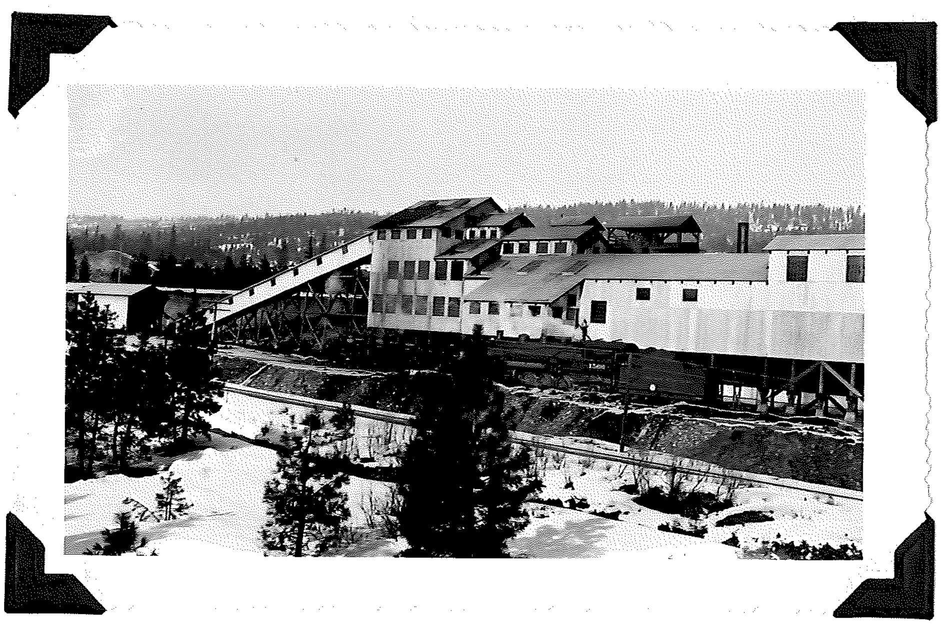


Plate XX. The central cleaning plant.

of 13 per cent ash and 3 per cent surface moisture. The refuse product, which averages 10 per cent of the feed, carries 60 to 70 per cent of incombustible.

The plant was designed and built entirely by the Northwestern Improvement Company. The first unit, including two Vissac jigs and an American Coal Cleaning table, was built in 1935. In 1937 another Vissac jig, a refuse rewash jig, and the Vissac dryer were added. To date a little more than 2-1/4 million tons of coal have been cleaned.

PAST PRODUCTION AND DISTRIBUTION

The Roslyn field production has been approximately 50,000,000 tons since its opening. Of this amount the Northwestern Improvement Company has mined, up to the year 1939, 41,654,124 tons of coal, distributed as follows:

Roslyn Mines	18,147,724 tons
Mine 3	6,329,254
Mine 5	5,350,058
Mine 7	7,605,270
Cle Elum	3,671,181
Mine 9	550,637
Total	41,654,124

Figure 15

COMMERCIAL OUTPUT FOR 1938 AND 1939

TOTAL ALL MINES	1938 TOTALS	1938 PER CENT OF TOTAL	1939 TOTALS	1939 PER CENT OF TOTAL
Raw				
3 in. lump	41164	7.5	29121	4.7
Mine run	9041	1.6	8164	1.3
3 in. steam	226	-	-	-
1-5/8 in. steam	822	.2	-	-
3/8 in. steam	5030	.9	4966	.8
Cleaned				
Egg	18469	3.4	17029	2.8
Egg nut	13082	2.4	41414	6.7
Nut	14714	2.7	17099	2.8
Nut pea	1667	.3	1313	.2
Pea	17094	3.1	19623	3.2
3 in. steam	284949	51.7	310318	50.4
1-5/8 in. steam	101638	18.5	86177	14.0
3/4 in. steam	39778	7.2	76019	12.4
3/8 in. steam	1698	.3	1874	.3
1/4 in. steam	1308	.2	2180	.4
TOTAL PRODUCTION	550680	100.0	615297	100.0

The channels of coal distribution by the Northwestern Improvement Company are The Northern Pacific Railway supply and the Continental Coal Company through which the commercial wholesaling is done. The railroad takes about 75 per cent of the output of the mines, and this coal is sent to locomotive fueling stations throughout the state. The Continental Coal Company with home offices located in Spokane, Washington is the sole distributor for N P Roslyn coal.

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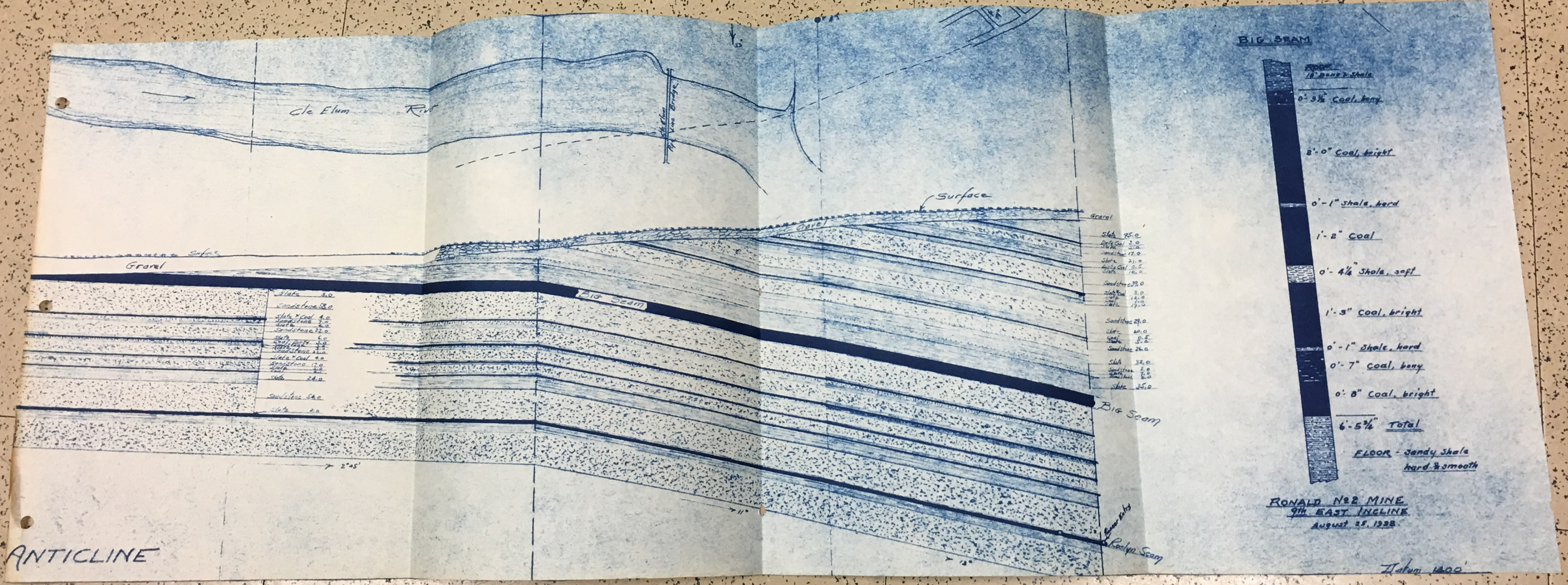
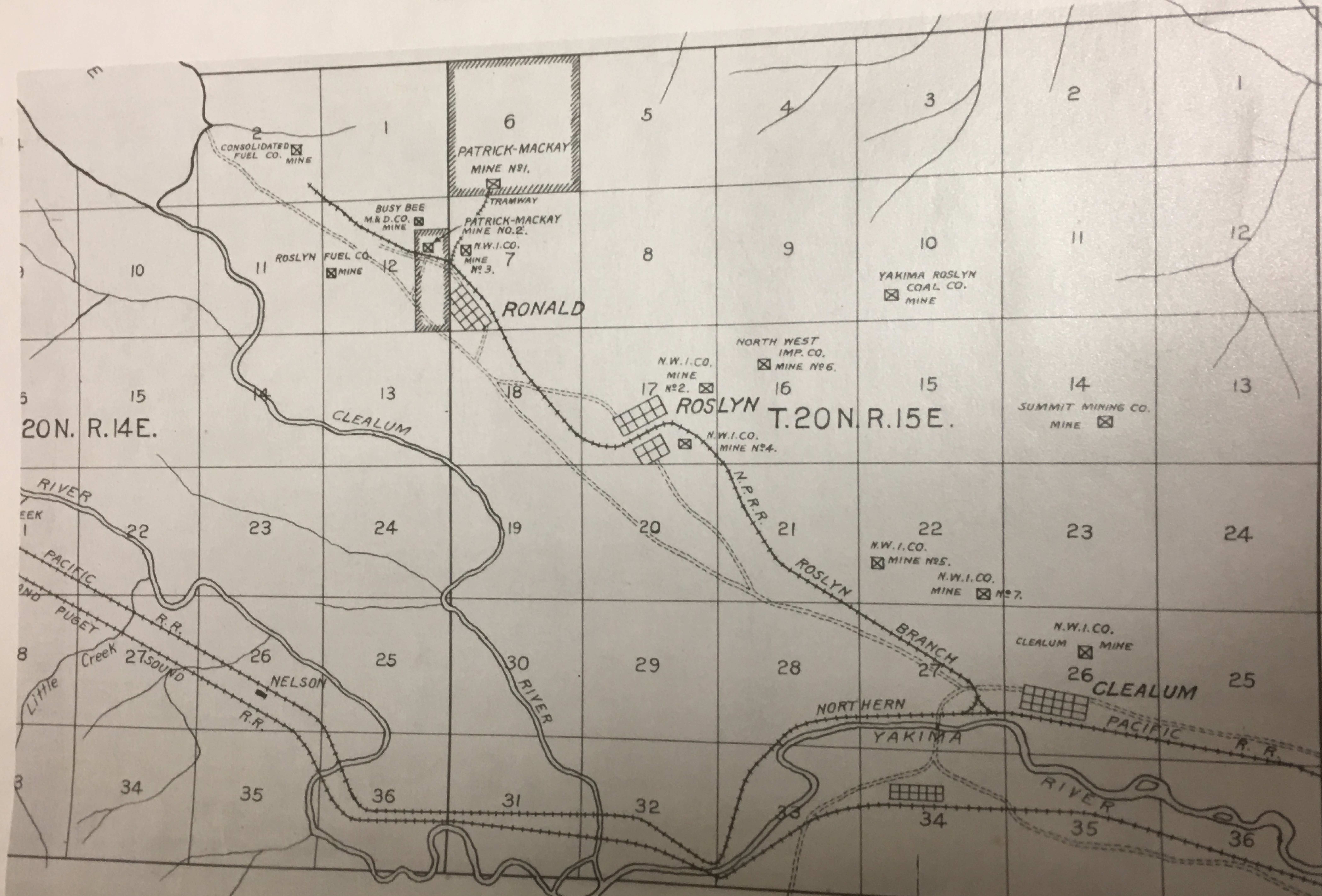

Cle Elum River
Surface
Gravel
Big Seam
Roslyn Seam
ANTICLINE
BIG SEAM
0'-3½" Coal, bony
2'-0" Coal, bright
0'-1" Shale, hard
1'-2" Coal
0'-4¼" Shale, soft
1'-3" Coal, bright
0'-1" Shale, hard
0'-7" Coal, bony
0'-8" Coal, bright
6'-5¾" Total
FLOOR - Sandy Shale hard & smooth
RONALD No 2 MINE
9th EAST INCLINE
August 25, 1938
Datum 1400'

THE ROSLYN-CLE ELUM COAL FIELD

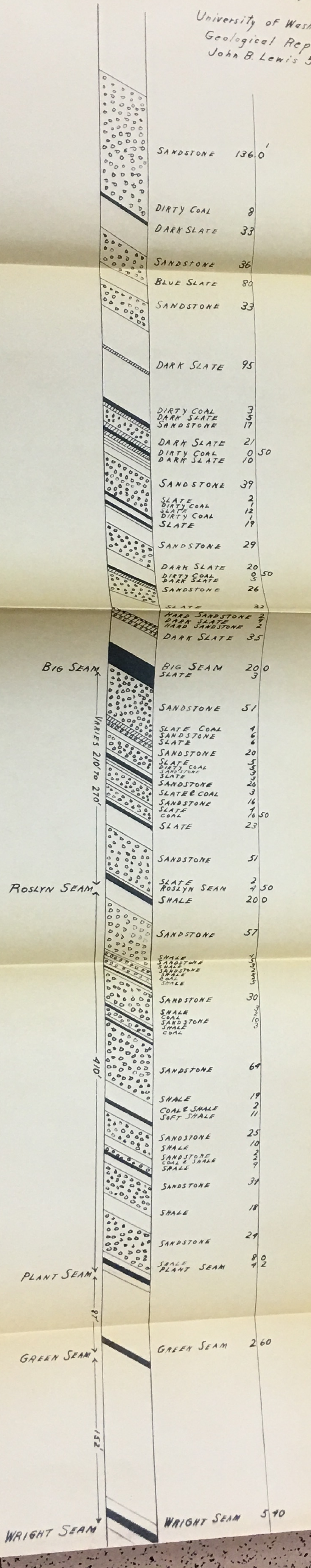


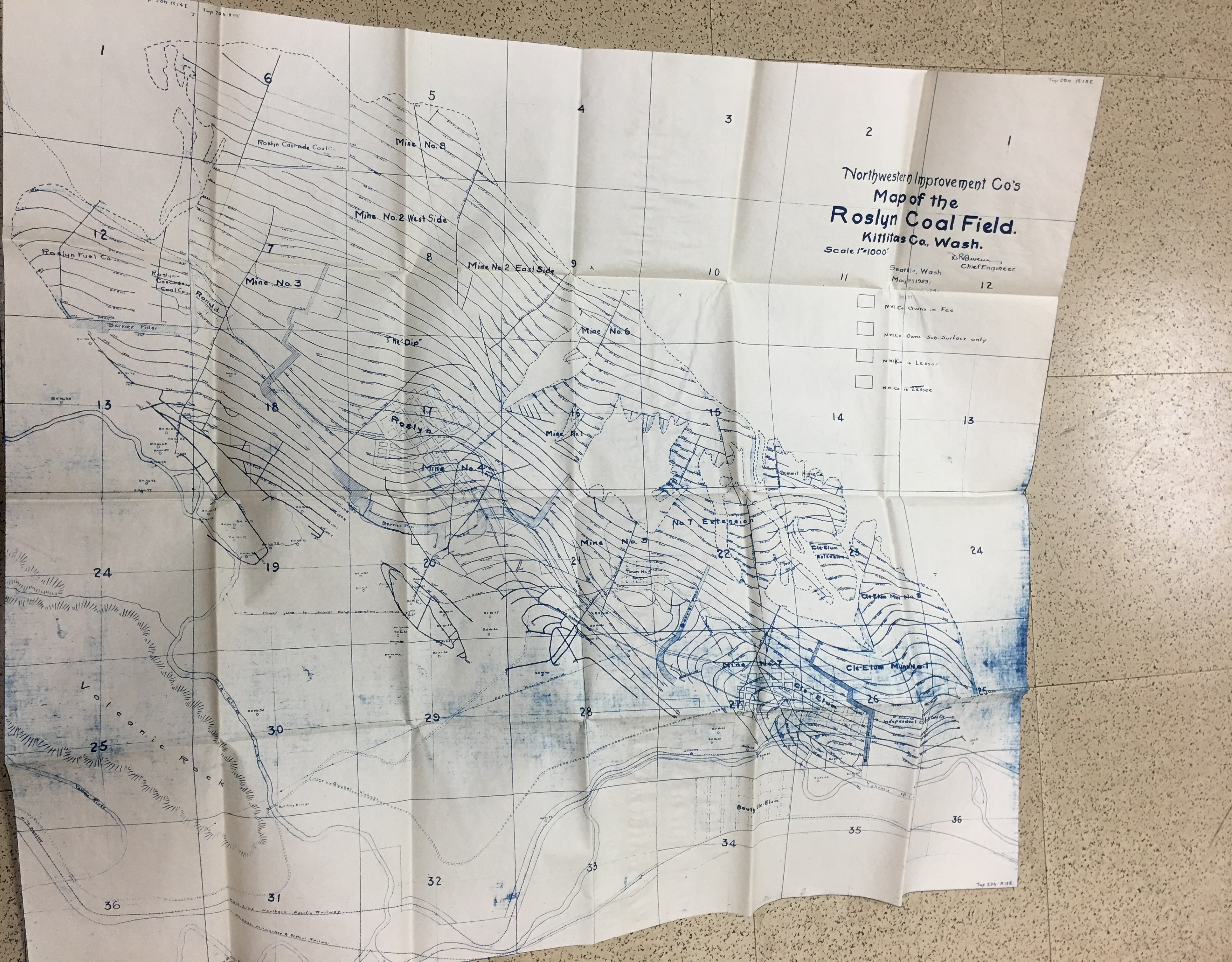
STRATIGRAPHICAL SECTION THRU PORTION OF ROSLYN COAL MEASURES

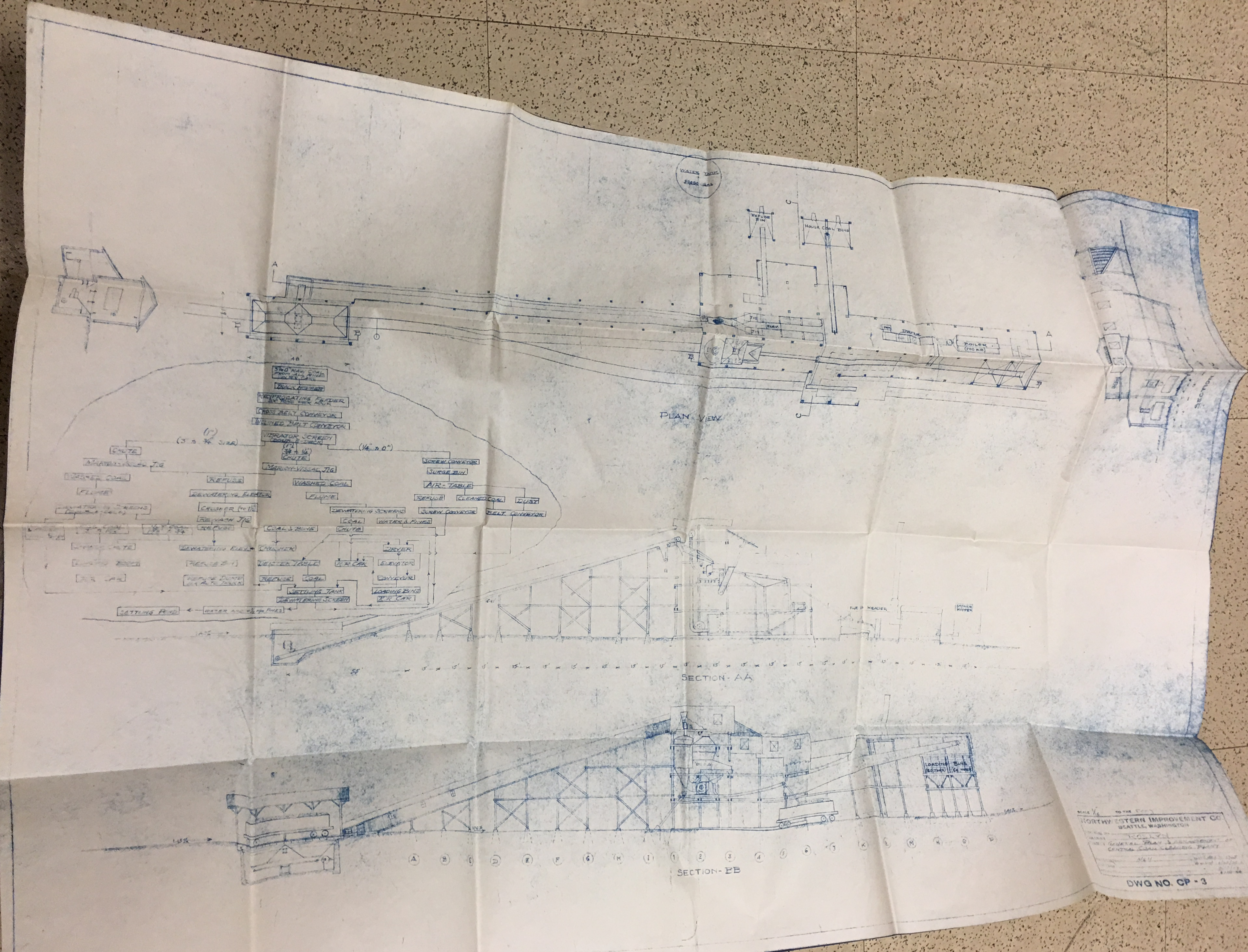
Scale 1" = 50'
Pitch 30°

Roslyn, Wash. May, 1939

University of Washington
Geological Report
John B. Lewis 5-13-39




Northwestern Improvement Co's
Map of the
Roslyn Coal Field.
Kittitas Co., Wash.
Scale 1"=1000'
Chief Engineer.
Seattle, Wash
NWI Co Owns in Fee
NWI Co Owns Sub-Surface only
NWI Co is Lessor
NWI Co is Lessee
Mine No. 8
Roslyn Cascade Coal Co.
Mine No. 2 West Side
Roslyn Fuel Co.
Roslyn-Cascade Coal Co.
Ronald
Mine No. 3
Mine No. 2 East Side
Barrier Pillar
Mine No. 6
The "Dip"
Roslyn
Mine No. 1
Mine No. 4
Mine No. 5
No. 7 Extension
Cle Elum Extension
Cle Elum Mine No. 2
Summit Mining Co.
Mine No. 7
Cle-Elum Mine No. 1
Cle Elum
Independent Coal & Coke Co.
South Cle-Elum
Volcanic Rock
Tp 20N R14E
Tp 20N R15E


PLAN VIEW
SECTION-AA
SECTION-BB
HOUSE COAL BINS
REFUSE BIN
BOILER
DRYER
LOADING BINS
TRACK HOPPER
RECIPROCATING FEEDER
CROSS BELT CONVEYOR
INCLINED BELT CONVEYOR
VIBRATOR SCREEN (DOUBLE-DECK)
(3 to 3/4 SIZE)
(3/4 to 1/4)
(1/4" to 0")
CHUTE
MARION-VISSAC JIG
WASHED COAL
REFUSE
FLUME
DEWATERING ELEVATOR
CRUSHER
REWASH JIG
DEWATERING SCREENS
COAL
WATER & FINES
COAL & BONE
SCREW CONVEYOR
SURGE BIN
AIR-TABLE
CLEANED COAL
DUST
BELT CONVEYOR
DEWATERING ELEV.
DEISTER TABLE
R.R. CAR
ELEVATOR
CONVEYOR
LOADING BINS
SETTLING TANK
DEWATERING SCREEN
SETTLING POND
NORTHWESTERN IMPROVEMENT CO
SEATTLE, WASHINGTON
GENERAL PLAN & ARRANGEMENT OF
CENTRAL COAL CLEANING PLANT
DWG NO. CP-3