PART III.

THE NON-METALLIFEROUS RESOURCES OF WASHINGTON, EXCEPT COAL.

BY

HENRY LANDES.

THE STATE CAPITOL, CONSTRUCTED OF CHUCKANUT AND TENINO SANDSTONE.

THE NON-METALLIFEROUS RESOURCES OF WASHINGTON.

BUILDING AND ORNAMENTAL STONES.

INTRODUCTION.

In order to be valuable for building purposes a stone must possess strength and durability and be of a pleasing color. In addition to these qualifications, it must be accessible to market. It must also be of such a nature that it can be worked into the proper shape without an undue amount of labor.

In regard to the first qualification, that of strength, its importance is usually overrated. Most stone is sufficiently strong to withstand the weight of any ordinary building, and it is only when the stone is required for heavy masonry construction that its crushing strength needs to be carefully considered.

The durability of a stone is a much more important factor. Buildings which are constructed of stone are presumably built to last, and careful attention should therefore be given to the durability of the material. Stones of different kinds are variously affected by the atmosphere. Sandstones which are composed mainly of quartz grains are affected according to the character of the cementing material. If the cement which binds the grains together is easily leached out by water the stone quickly crumbles away, but if the grains are bound together with silica or some other insoluble material the stone is very durable.

Granitic rocks and nearly all of the finer grained igneous rocks make very durable building stones. Gneiss and schist are apt to scale off along their bedding planes and when they are used in building should always be laid on their flat side, and never on edge. The same rule applies to all stones that show any signs of bedding.

Serpentine, while rather a soft rock, seems to be little affected by atmospheric agents, and when not too badly fissured lasts for a long time. Marble and limestone are somewhat soluble in water and in time weather badly, as may be seen in any old cemetery where the lettering on the marble monuments is often entirely obliterated.

The commercial value of a building stone is largely influenced by its color. Light, fresh colors are in more popular demand than are the more somber tints. A very dark stone of any shade is rarely used in building except perhaps for foundation work.

The cost of putting a stone on the market depends, 1st, on the accessibility of the quarry, and 2d, on the ease with which the stone can be quarried and dressed to the proper shape. The quarries thus far opened in Washington are practically all close to a large town or city, or alongside a railroad, or convenient to navigable water. Stone will not bear the expense of a long haul unless it be of more than ordinary value. Good stone is so widely distributed that builders usually prefer to use that near at hand rather than go to the increased expense of importing it from a distance.

More important even than accessibility, from the standpoint of cost, is the ease with which the stone can be quarried and dressed. Some stones are so extremely hard to work that although they are very desirable otherwise, they can not be used for building purposes. The soft sandstones of Western Washington are very easily worked, and it is to this quality rather than to the beauty or durability which they may possess that they are indebted for their present development. Granite is considerably harder to work than sandstone. It can not be sawed economically and it has no bedding planes to assist in splitting it into the required shape. Advantage is taken of its joint planes wherever possible. Many of the finer grained igneous rocks are still more difficult, and it is only when they take a fine polish and are suitable for monumental purposes that it pays to work them. Serpentine is soft and easily sawed and polished. Many stones otherwise desirable vary so rapidly from one shade of color to another that no large quantity can be had of the same shade, so that when stone is to be used in the construction of a large building it is important to ascertain beforehand if a sufficient amount can be obtained that will be uniform in color and texture.

Washington possesses an unusual variety of rocks suitable for building and monumental purposes, only a few of the most accessible of which will be enumerated here.

In western Washington sandstone belonging to the Tertiary period occurs in a large number of places about the borders of Puget sound and farther south towards the Columbia river. It shows considerable variation in color and hardness, but is usually of a light grayish or bluish color, weathering sometimes to a light buff for a short distance below the surface. It is never very hard and is easily quarried and cut into the required shape.

In eastern Washington between the Cascade mountains and Columbia river large areas of sandstone of Tertiary age occur in several places along the Great Northern and the Northern Pacific railways in Chelan and Kittitas counties. They have never been used to any extent for building purposes and are probably too soft to be of much value.

Coarse sandstone and conglomerate of Cretaceous age constitute the bed rock of the northern islands of the San Juan group. The sandstone varies in color through different shades from gray to brown. On Waldron island it forms cliffs two or three hundred feet high along the shore. It also occurs on Sucia, Matia, Spieden, Stuart and the northern part of Orcas island.

Granite occurs in a number of places both in eastern and western Washington. Along the Great Northern Railroad it occurs at intervals all the way from Index to within a mile of Leavenworth. It is also known to occur between Snoqualmie and North Bend and on Mount Si, on the line of the Snoqualmie branch of the Northern Pacific Railway.

East of the Cascades granite forms the country rock in a number of places in Kittitas, Chelan, Okanogan and Ferry counties, in none of which, however, has it been used for building purposes, because of an absence of any demand. Near Spokane and at Medical Lake granite also occurs which has been quarried extensively. Other small areas have been noted in the canyon of Snake river.

The basalt forming the Columbia lava plain is not a high grade building stone. It is too dark, and is too hard to work into shape. It has been used to a considerable extent for bridge piers and in foundation work for buildings. Other lavas lighter in color and more suitable for building purposes are found in a number of places in the Cascade and Olympic mountains, but have not yet been utilized. Serpentine, valuable for building and ornamental purposes, is extensively quarried at only one place, viz., Valley, Stevens county.

GRANITE QUARRIES.

Index.

The Index granite works, owned by Mr. J. A. Soderberg, have for the last ten years enjoyed a practical monopoly of the granite business in the Puget sound region, except for the finer varieties used in monumental work. Large quantities of this granite have been used for street curbing, monument bases, foundation work for buildings, and many other purposes. It is a light gray biotite-bearing hornblende granite with crystals of orthoclase and plagioclase feldspar. The great preponderance of feldspar over quartz carries the rock near to the border line of syenite. It makes a strong, substantial building stone but will not take a good polish. It occurs in inexhaustible quantities in the country about Index, the whole core of the mountain being made of it. The quarry is located alongside of the railway track, about half a mile west of the railway station at Index. The rock is blasted loose with black powder and split up into blocks by means of plug and feather drills. Cars are run on the side track and the blocks of stone are loaded by means of derricks. The number of men employed varies with the number of orders on hand. During the summer of 1901 about forty men were employed continually.

About one-half mile east of Index a new granite quarry has been opened lately by Mr. T. S. Ellis, of Seattle. It is very similar to the Soderberg stone, but is a little brighter in appearance. It is being used for the piers of the new Arcade building at the corner of Second avenue and Marion streets, Seattle. It is also being used for monument bases by some of the marble companies in Seattle. The demand for granite in western Washington is increasing very fast, and there is no doubt but that both of these Index quarries will soon be developed on a much larger scale. They are very favorably located with regard to the railroad, and the stone is so situated that it can be quarried at a minimum expense.

Spokane.

Spokane is very favorably situated with regard to building stones. There are several granite quarries very near the city which are worked as occasion requires. At the present time, however, none of the quarries are being worked continuously. In the quarries east of the city the stone is taken out by contractors who only aim to fill their standing orders, and who do not keep a supply on hand or do any work when there are no orders ahead. The stone varies slightly in texture, but is mostly a very light gray muscovite-biotite granite with large crystals of feldspar. One of the quarries belonging to the Washington Monumental Company is in a dark gray biotite-hornblende gneiss, closely banded. The stone is used largely for street curbing, monument bases, and copings for building purposes.

Medical Lake.

The quarry at Medical Lake, about sixteen miles southwest of Spokane, is in granite very similar to that found about Spokane. It is located on an outcropping of granite surrounded on all sides by basaltic lava, being one of the few places within the lava field where the older rocks crop out on the surface. The quarry has been in operation for a number of years. Most of the product goes to Spokane and surrounding towns. Some of it has been shipped as far west as Seattle where it was used in the Administration building of the State University.

Snake River.

The Snake River Granite Quarry, belonging to Mr. Miles C. Moore, of Walla Walla, is located on a ledge of granite at the bottom of Snake river canyon at a point where the river has carved its way through the basalt and laid bare the older formation. The quarry is situated in Whitman county, about twenty miles below Lewiston, in township 13 N., R. 43 E. The rock occurs on both sides of the river and is capped by basalt probably a thousand feet in thickness. A recently constructed branch line of the Oregon Railway and Navigation Company runs directly through the quarry. Before the railroad was built the river steamers landed alonside and the stone was hoisted aboard by means of derricks and carried down the river forty miles to Riparia, where it was transferred to the O. R. & N. Railway.

The stone is a light gray biotite-hornblende granite with large crystals of clear othoclase feldspar. It is very hard and unweathered and makes a handsome and durable building stone. About fifty thousand cubic feet of it was used in the new Government building at Portland, Oregon. The piers and buttresses of the Northern Pacific bridge at the mouth of the Snake are also constructed of this stone. It is used largely for street curbing in Spokane, Portland, Walla Walla, and other cities.

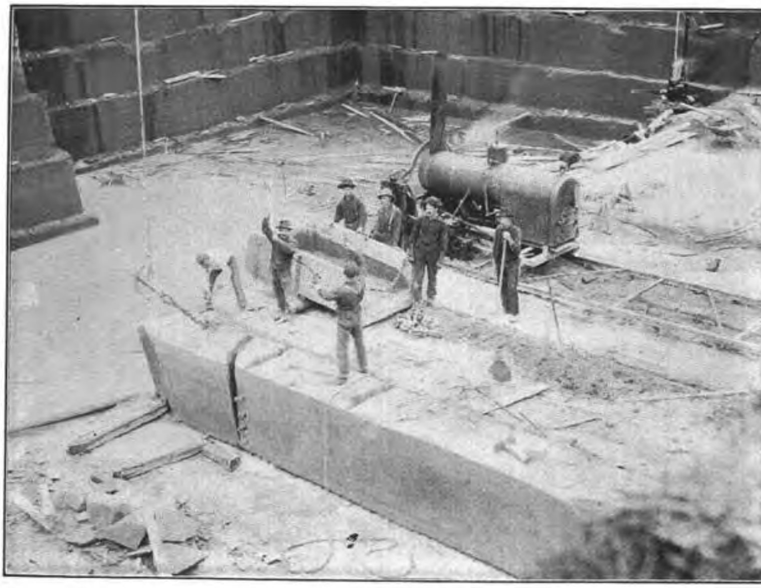
Farther up the Snake than the locality last mentioned, near the mouth of the Grand Ronde river, Mr. Moore has another granite quarry, but which is not as accessible as the first one. The stone is a dark gray hornblende-biotite granite, rather fine grained. It takes a beautiful polish and has been used to some extent for monumental work, for which purpose it is admirably suited. Some of it has been brought down to Lewiston on scows and from there re-shipped by steamers. Navigation on the upper Snake is very precarious and until better shipping facilities are obtained the quarry will be rather handicapped. Steamers have at times of high water ascended the river to points above this quarry, but for practical purposes the head of navigation of the Snake seems to be at Asotin.

SANDSTONE QUARRIES.

Chuckanut.

The Chuckanut quarry is situated on Chuckanut bay, about five miles south of Whatcom. The stone is a bluish sandstone very similar in appearance to that of the Tenino quarry, but is considerably harder. Like all sandstones of this class it hardens on exposure to the atmosphere so that in buildings like the Dexter Horton bank building of Seattle, where it has been in position for a number of years, it is now very hard. A compression test made at the Watertown arsenal, Massachusetts, gave an average crushing strength of 11,389 pounds to the square inch. This strength is sufficient for all of the weight that will ever be brought to bear upon the stone even in the largest buildings.

The stone occurs in a high bluff overlooking the bay and the beds pitch towards the bay at a steep angle. As the rock is blasted loose it flakes off along the bedding planes and is allowed to slide down to the bottom of the slope. When required for dimension stone the large blocks are loaded onto trucks and



TENINO SANDSTONE QUARRY.

MILL FOR SAWING STONE, TENINO SANDSTONE QUARRY.

run into the mill where they are sawed into the required sizes by sets of gang saws. The mill is supplied with two sets of gang saws, and is run by steam power. A half dozen or more slabs are sawed at the same time, the number depending upon the thickness. The sawing is so arranged that when the stone is put into a building the bedding planes shall lie flat. Most of the orders call for sawed stone of specified size.

The quarry was first opened up by Mr. Henry Roeder. He began operations at a point a short distance south of the present workings in the early seventies and moved to the present location at a much later date.

The following are a few of the important buildings constructed wholly or in part of this stone: U. S. custom house, Port Townsend; U. S. custom house, Portland, Oregon; court house building, Port Townsend; Dexter Horton building, Seattle; new high school building, Seattle; Thurston county court house, now the state capitol, Olympia.

Sucia Island.

On Sucia island, the most northern one of the San Juan group, a quarry was opened some years ago in a dark brown sandstone of Cretaceous age. The quarry is located on the water's edge so that deep water vessels may land alongside and the stone hoisted by derrick from the quarry to the deck of the vessel.

The stone is a hard, massive sandstone of such very coarse texture that it approaches a grit. It is not an easy stone to work and is probably more suitable for heavy masonry work than for ordinary building purposes. The United States drydock at Port Orchard was constructed of stone from this quarry.

Tenino.

By Milnor Roberts.

At a number of points in the neighborhood of Tenino, fifteen miles southeast of Olympia, the Eocene sandstone has been quarried as a building stone for a number of years. In some of the pits that have been opened, while the stone is of excellent quality in small masses, it occurs interbedded with thin layers of shale or lines of very hard concretions, which reduce or completely destroy its commercial value. Coal is found near by in the same geological horizon.

The only quarries in this region that are being worked at present are in a group at Tenino, controlled by Messrs. Russell and Fenton. Stone was first taken out in 1889, since which time the output has been practically continuous, amounting to a gross total of one and one-third million cubic feet. As almost every cubic foot of the stone is of a quality fit for the market and the waste in handling is slight, the yield of the quarries to date is seen to have been considerable. It is impossible to say what are the limits within which stone of the same lithological character may be found, since prospecting and development alone can prove that, but the indications are that it occurs in abundance.

The stone is a rather fine-grained sandstone, light greenish gray in color, free from inclusions and of an even texture. The composition is given as follows:

Silica	74.00 per cent.	Oxide of Iron	6.65 per cent.
Alumina	13.51 per cent.	Calcium oxide	3.61 per cent.
Magnesium oxide	1.65 per cent.	Sulphur trioxide	none.
Phosporous pentoxide	none.		

A sample was tested by the ordnance department of the United States army at the Watertown arsenal July 3, 1893 — compression test No. 9256. The first crack occurred under 173,000 pounds pressure, and the ultimate strength was found to be 176,100 pounds, or 6,879 pounds per square inch. Under the microscope the rock shows a large proportion of well-rounded grains of white quartz, about one-tenth of a millimeter in diameter. There are some dark colored grains of quartz present, along with crystals of muscovite, biotite, hornblende, and other minerals. A tendency to exhibit a banded structure is apparent, but it is more noticeable in large masses in the quarry than in a block or hand specimen. The bands seem to be due to layers of finer and darker colored material, and represent the bedding planes of deposition. The dip is about 15 degrees, pointing a few degrees west of south.

Two main quarries have been opened up in the north side of a hill, half a mile northeast of the station of Tenino, on the Northern Pacific Railway (from which a spur enters the yards). The larger pit, used as a reservoir at present, extends 225 feet along the hillside, is over 100 feet wide, 50 feet deep at the back, and 25 feet deep in front, the difference being due to the slope of the surface. The newer pit, a few steps distant to the northwest, is 180 feet long east and west, 85 feet wide and about 30 feet deep. A swinging crane with 70-foot boom stands on the edge of this pit in the middle of the south side.

The stone is cut out by two steam channelers into blocks four and one-half feet thick. A line of track made in permanent sections is laid along the floor close to the wall. The channeler, which carries its own boiler and engine, moves back and forth on the track for a distance of twenty feet, while the chisels work in vertical grooves with a steady stream of water running in. Ten or twelve cuts are needed to reach a depth of 54 inches, occupying from half an hour to an hour's time. When grooves have been cut along the whole length of track, the channeler is lifted by the crane and the track relaid for a parallel line of cuts. Other grooves are cut similarly at right angles to these, then the blocks are loosened by wedges driven in at the bottom. The crane hoists the blocks out of the pit, and places them on a small flat car, turning them on edge if they are to be cut by the gang saws. This is done in order that the sawn blocks when used in masonry shall lie in the same relative position as in the quarry.

The gang saws are four in number, carrying from one to eight saws apiece. Each saw is simply a flat piece of steel, ten feet long, five inches wide and three-sixteenths of an inch thick, without teeth, and depending for its cutting power upon the speed with which it runs, and upon an abrasive in the form of coarse steel filings, fed with water into the cut. The saws are set on edge, parallel, to cut downwards, and are bolted at the ends like a bucksaw, the distance separating any two saws determining the thickness of the slab. The rectangular frame that holds them is swung from a shaft placed at right angles to the line of cut. The shaft may be raised or lowered by means of a positive feed gear. The gangsaw is driven by a rod connected directly with the piston of a steam cylinder. The limit of speed in cutting depends upon the rate at which the saws may be forced down against the stone without buckling. An average of more than one foot per hour is usual, but with plenty of steam and careful feeding of the steel filings, a speed of two feet may be attained.

That the sawing is not the most expensive part of the quarryman's work may be judged from the fact that slabs one foot thick sell at the rate of 45 cents per superficial foot, eight inches thick at 35 cents, four inches thick at 20 cents, and two-inch slabs at 16 cents per square foot of surface. When large quantities of a certain sized stone are ordered it may be produced much cheaper than this. It is the custom here, as elsewhere, to cut stone at the quarry to the proper size ready for placing in the building, mainly to save freight on waste material. About thirty or forty men are employed, the number depending on the orders at hand.

The Tenino sandstone has been used in many large buildings throughout the state and in Oregon and California, both as the principal material of construction and as a finishing stone. The State capitol now under construction, the Bailey building in Seattle, Calvary Presbyterian Church in San Francisco, and several business blocks in coast cities may be cited as examples. The stone seems to harden on exposure and wears well. Its refractory nature is proved by its continued use under boilers and as a lining for open fireplaces. Other uses to which it has been put with satisfactory results are as an ornamental stone for fountains, monuments and mantels, and in the shape of rubble or quarry waste to form concrete.

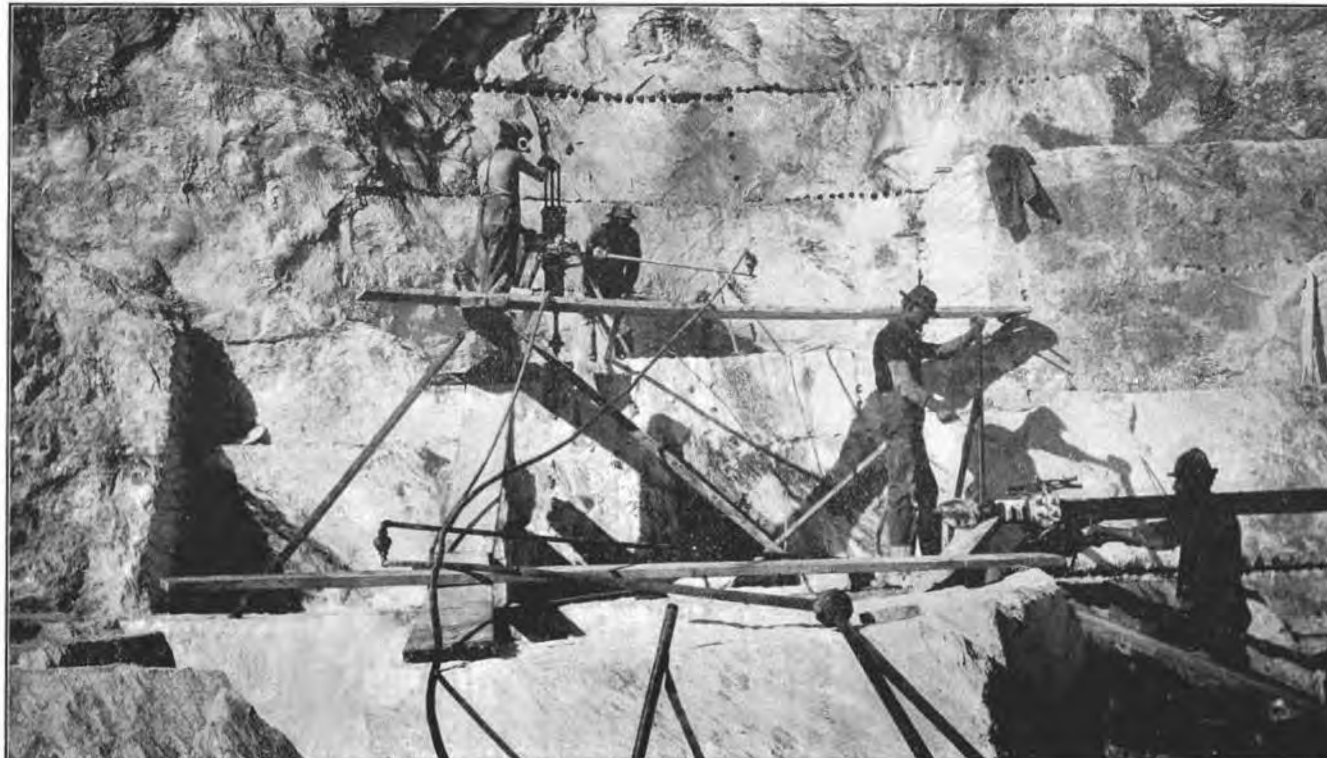
Wilkeson.

The Wilkeson quarry is the property of the Northern Pacific Railway Company and is situated at the town of Wilkeson, Pierce county. The rock is a sandstone belonging to the coal series. It is bluish-gray in color and is streaked with brown iron rust and carbonaceous matter. When found free from these defects it has a fresh pleasing appearance and makes a hard, substantial building stone, but it is difficult to get a large quantity of it that is uniform in color and texture. The quarry has not been in active operation for the last seven or eight years. Occasionally the railway company quarries some of the stone for its own use, but does not place any of it on the market.

SERPENTINE QUARRIES.

Valley.

The United States Marble Company, of Spokane, is operating a serpentine quarry near Valley, about fifty miles north of Spokane, on the line of the Spokane Falls & Northern Railway. It is the largest quarry in the state, both in the number of men



QUARRY OF U. S. MARBLE COMPANY, VALLEY

employed and in the value of the output. It is comparatively a new concern, only having been in active operation since July, 1898, but they have already spent $75,000 in developing the property and in equiping the plant. The property consists of a compact group of eighteen claims on Greenway mountain, including the serpentine dike upon which the quarry is located; also eighty acres of marble land within a mile of the railroad, upon which no work has yet been done except a little surface prospecting. The dike of serpentine lies between a foot wall of black marble and a hanging wall of silver gray slate, both valuable, but neither of which are being worked at present. The dike, which is about six hundred feet wide, has been traced in length a distance of fifteen hundred feet and has a known depth of seven hundred feet. It varies in color from light gray to deep green, the green being the most valuable. The company has given to the latter the name Royal Washington serpentine. Three machine drills are now at work in the quarry and as soon as the installation of the new power plant is completed the number of drills will be increased to eight. No powder of any kind is used in quarrying, as the stone is too valuable to allow any of it to be shattered by blasting. It is quarried out in as large blocks as can be readily handled by team, and hauled to the mill which is situated at the base of the mountain. The company claim that they can quarry out blocks of the Royal Washington of fifty tons weight, if necessary. After the blocks are quarried they are loaded on a wagon by means of a derrick and taken to the mill. The mill is equipped with the very latest machinery for sawing, grinding and polishing the stone into any desired shape. There are two sets of gang saws, a rubbing bed thirteen and a half feet in diameter, three polishing machines, four lathes, and a number of other pieces of machinery.

The camp, consisting of bunk house, kitchen, office, barns, store building, etc., is situated on the mountain side several hundred feet below the quarry. The general store not only supplies the company's own employees, but also does considerable business with the nearby mining camps. A warehouse has been built at Valley, where the finished stone is stored awaiting shipment.

Since the fall of 1900 the mill and quarry have been operating night and day continually in an effort to keep up with the orders. Many orders in fact have had to be refused until larger machinery could be installed. There are now over eighty men on the company's pay roll and they are working on orders for several months ahead. Most of the orders are for monumental and building stone, both for interior and exterior finish.

At the Pan-American Exposition at Buffalo the company exhibited a beautiful mantle showing the various colors and qualities of their stone. The exhibit was awarded a silver medal.

The marble and slate deposits which up to the present time have been entirely untouched offer a promising field for future activity. The present limited demand for these two stones can be largely increased and the company is now making preparations to open up these deposits and put the products on the market.

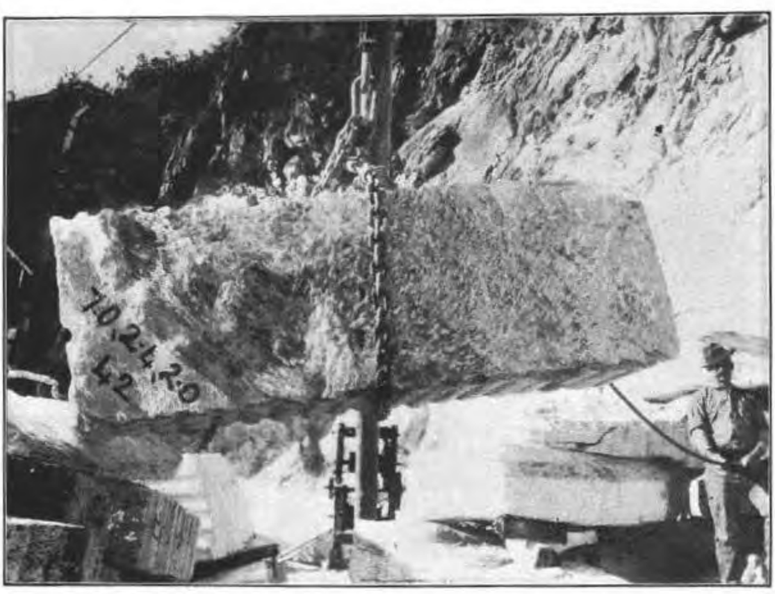
MARBLE QUARRIES.

Stevens County.

At a number of places in Stevens county marble of an excellent quality and of a very pleasing color is found. Blocks of large size may be quarried, and a monumental stone of superior excellence obtained. In some instances the marble lies convenient to the railway so that the quarry products may be easily shipped to market. A great deal of interest is now being taken in these marble deposits and it is expected that a number of large quarries will soon be put in operation.

The marble of Stevens county belongs to the ancient rocks now so highly metamorphosed that they have become quite crystalline. Such rocks are characteristic of the northern Cascades and the Okanogan highlands, extending eastward to the Idaho line. The marble occurs in occasional masses among the granites, gneisses, and schists wherever erosion has not yet removed it.

NEW QUARRY LEVEL. U. S. MARBLE COMPANY, VALLEY.



QUARRY OF U. S. MARBLE COMPANY, VALLEY.

CLAY MATERIALS.

INTRODUCTION.

The clays which are being used in the state in the manufacture of different varieties of brick, drain tile, sewer pipe, terra cotta products, etc., belong to several different geological formations. The most important clay deposits may be divided according to their method of occurrence into glacial clays, residual clays, and clay shales.

Glacial clays are found very generally distributed over all of the glaciated region of western Washington. They are composed of the fine flour ground up by the glacial ice and deposited by streams in the numerous small lakes and ponds which abounded throughout the region during the time when the ice was disappearing. The clay beds occur very irregularly, interstratified with sands and gravels or embedded in the till, and the quantity in any one place is largely a matter of speculation. The brick yards which utilize this clay are all located either on the shores of the Sound or on railway lines close to the larger centers of population. The clay is used chiefly in the manufacture of common red brick, and this industry has grown to be one of considerable magnitude. During the year 1901 the brick yards of Seattle alone made over thirty-nine million red brick, having a total value of nearly $400,000.

Residual clay is found only in the non-glaciated parts of the state. It is the residue left after all the soluble parts of a rock have been carried away. In western Washington, between Puget sound and the Columbia river, this clay is very thick in places, being formed largely by the weathering of shale. Shale is merely consolidated clay, so that the line of distinction between them is not very clearly drawn. Occasionally the clay beds are not very deep, and graduate insensibly into the solid shale beneath.

In eastern Washington the fine residue left by the decomposition of basalt makes a very good red brick. Throughout most of the region where the basalt occurs the brick that is used is made from this material. Small kilns are in operation in a number of places to supply the local demand.

The more expensive products, such as cream-colored pressed brick, red pressed brick, vitrified brick, drain and sewer pipe, and terra cotta articles are all manufactured from the older shales and clays which are described in connection with the different manufacturing plants which use them.

DENNY CLAY COMPANY.

By Milnor Roberts.

The clays used by the Denny Clay Company, of Seattle, are all obtained from the company's mines at Kummer and Taylor on the Columbia & Puget Sound Railroad. At Kummer, in Green river canyon, the variety known as "flint" clay is mined from a seven-foot vein at the foot of an incline 700 feet long. The clay used for making sewer pipe occurs in a mass 60 feet thick, which is treated just as a coal bed would be, and mined by breasts. A tunnel has been driven in at a point 20 feet above the high water mark of Green river. On account of the strength of the clay wide breasts and small pillars have been found safe to use. At Taylor, 20 miles to the northeast, the quality of the clay renders it suitable for making pressed brick, flue lining and terra cotta.

George W. Kummer, general manager of the company, who has been experimenting here for a dozen years past, and is familiar with Eastern methods of manufacture, has found that unlimited combinations can be made out of these clays, to produce practically all forms of brick, pipe and fire-proofing material. For instance, the highly refractory but non-plastic "flint" from Kummer, when mixed with a proper proportion of the Taylor clays, makes a highly refractory yet strong fire brick. Again, as a matter of experiment, pressed brick for facing buildings has been produced in twenty-three distinct shades of color, from the seven different kinds of clay at hand. Doubtless in some of these cases the result has been due to skillful handling in the kiln, varying the degree of heat, muffling, using direct fire or radiated heat. In burning a kiln full of brick it is unusual to find absolute uniformity of color throughout, as different conditions may prevail in different parts of the kiln, and for similar reasons it is difficult to match a peculiar color with exactness.

In the following analyses, made by W. J. Rattle, of Cleveland, No. 1 is the flint clay from Kummer, Nos. 2 and 3 are from Taylor, and No. 4 is a fine sand from Kummer which is mixed with clays to increase their percentage of silica, and add solidity to the brick.

COMPONENT PARTS.	*No. 1*	*No. 2*	*No. 3*	*No. 4 Fire sand*
Silica	33.44	41.36	72.30	78.60
Alumina	45.23	40.49	19.95	13.08
Lime	1.60	.62	.52	1.22
Magnesia	3.61	Trace	Trace	.648
Iron peroxide	1.57	....	....	2.29
Iron sesqui oxide	....	.71	.71	.114
Alkalies	1.44	....	.114	....
Soda and potash	....	1.47	2.98	....
Common water	16.44	15.29	3.50	3.30

The works of the Denny Clay Company are situated one mile southeast of Georgetown, and six miles from the center of Seattle on the line of the Northern Pacific Railway and the electric line to Tacoma now in process of construction.

Clay arriving by car from the mines is piled under sheds, each class by itself. Certain combinations of clays being required for certain products, the mixing is done by taking the proper number of loads by wheelbarrow from each pile and feeding them together into the crushing pan. Coarse lumps are first broken in a jaw-crusher, from which an endless belt carries the broken material to the pan. The latter is a form of Chilian mill, consisting of a circular steel pan nine feet in diameter, with flat bottom and vertical sides eighteen inches high. Power furnished to a central column with bevel gearing causes the pan to turn at the rate of 25 to 30 revolutions per minute. Two steel-tired grinding wheels, four feet in diameter and eight inches thick, rest vertically on the bottom of the pan and turn on a horizontal axis which is hung on springs. The outer edge of the pan bottom for a width of two feet is a screen surface, with slotted openings one-fourth inch by two and one-half inches, radiating from the center. The clay is both crushed and ground by the rollers, and forced to the outer edge of the pan, where the fines fall through the screen to a lower plate and are discharged into an elevator. Stationary steel guides set in the pan shunt the contents in toward the center at every turn, thus bringing back under the grinding wheels all material that fails to pass the screen.

The elevators used for clay are canvas and rubber belts with paddles attached, running in a trough. From the grinding pan the fines are carried up to the third floor and run through a trommel. The coarse is allowed to run back over a long screen, returning to the grinding pan. The size of the mesh used in the trommel and screens depends altogether on the purpose for which the clay is needed, but ordinarily it varies from ten to twenty holes per linear inch. Screened clay falls through a chute to the mixing or "wet" pans, two in number, placed side by side and handled by one man. The apparently simple work of tempering the clay by mixing with water, in reality requires great experience in handling clays, and a knowledge of their physical properties, especially their plasticity, therefore the man who fills the position of mixer is more responsible than anyone else for the burning and wearing qualities of the product. The pans are similar in construction to the grinding pan, but as there is no outlet for the mixture through the bottom, a long-handled scoop set on a pivot is used to raise the tempered clay and dump it into an elevator.

The main building in which the brick and pipe presses are placed measures 80 by 150 feet and is three stories high. A complete heating plant with steam radiator pipes under the first floor keeps the air in the building at the proper temperature for drying green material. The engine and boiler plant in an adjoining building generates 300 nominal horse power. In order that the buildings may be free from the jar caused by the working of heavy machinery and the revolution of the line shaft, the latter is supported on several blocks of concrete weighing ten tons each set in the ground, and the mixing pans have similar foundations. Fourteen down-draft circular kilns are in use, some of them being of unusual size, 34 feet in internal diameter. The fuel is obtained from a coal bed overlying the clay in the company's mine at Taylor.

The total force of men employed numbers 145, of whom two-thirds are at the works, and the rest in the mines. The main products of the works are as follows:

Pressed facing brick, made in a number of different shades as above stated. Standard colors are kept on hand in large supply, and others are made to order. This brick finds a market in Seattle, Tacoma, Victoria, Vancouver, Spokane, Walla Walla, and Portland.

Vitrified or annealed paving brick, for street paving. Annealed and glazed brick is rapidly growing in favor as a street paving material,

DENNY CLAY WORKS, SEATTLE.

owing to its great strength and durability under heavy traffic, its smoothness, cheapness and the speed with which it can be laid.

REPORT OF MECHANICAL TESTS,

Made with the U. S. testing machine (capacity 800,000 pounds) at Watertown Arsenal, Mass., June 13, 1894.—Material contributed by the Denny Clay Co., at the World's Columbian Exposition, Chicago, Illinois.

DESCRIPTION.	DIMENSIONS.			Sectional area....	Weight dry....		ABSORPTION OF WATER.			First crack....	ULTIMATE STRENGTH.	
	Height....	Compressed surface.					Total....	By weight.	By volume		Total....	Per Sq. In....
	In.	In.	In.	sq. in.	lbs.	oz.	oz.	Per ct.	Per ct.	Lbs.	Lbs.	Lbs.
Facing brick: Denny Clay Co........	2.45	8.98	4.48	40.23	6	13¾	6¼	5.6	11.00	250,000	505,800	12,573
Facing brick: Denny Clay Co........	2.38	8.89	4.45	39.56	6	6¾	6	5.8	11.00	309,000	519,700	13,137
*Vitrified paving brick: Denny Clay Co........	4.23	8.78	2.70	23.71	7	12¼	½	0.4	00.86	49,000	288,100	12,151
Vitrified paving brick: Denny Clay Co........	2.61	8.76	4.08	35.74	7	12¼	1	0.8	1.85	55,000	761,000	21,293

*Tested on edge.

Sewer pipe, glazed, varies in diameter from 3 to 24 inches inside measurement, length two feet.

Drain tile, made in one or two-foot lengths, size from 2 to 6 inches.

Chimney pipe, tops and flues, made of high grade fire clay, in all necessary forms.

Hollow vitrified foundation blocks, in two sizes, 8½ or 12 inches in square section, and from 3 inches to 3 feet long. Being vitrified, they are impervious to moisture, while the air space in each block is a poor conductor of heat from within or cold from without.

Fire brick, in all the usual shapes, proved to possess excellent qualities as locomotive brick, furnace blocks, linings, etc. The following results are from tests made by J. W. Reilley, major ordnance department, U. S. A., Watertown Arsenal:

Area exposed to crushing..	37.97 square inches
Average weight under which brick cracked...........................	29.95 tons
Average force required to crush brick..............................	52.49 tons
Weight when dry..	5.135 pounds
Percentage of water absorbed......................................	12

Ground fire clay. The flint clay from Kummer is mixed with a plastic clay, and by a special process of treatment is brought to a plastic condition, meanwhile retaining its refractory qualities. The mixture is dried, pulverized, and shipped in barrels, to be used as a cement in laying fire brick. From five to seven hundred pounds are required to lay one thousand brick, making the joints as thin as possible.

Sidewalk and floor tile, both plain and ornamental, partition tile of fire clay, ornamental ware, terra cotta, etc. Two small kilns are devoted to the manufacture of such ware.

Acid brick, made from very siliceous clays free from alkalies, for special use in acid and powder works.

LITTLE FALLS FIRE CLAY COMPANY.

By Milnor Roberts.

Along the Cowlitz river, a few miles above the crossing of the Northern Pacific Railway at Olequa, and two miles east of the station of Little Falls or Sopenah, an excellent exposure of clay shale occurs in the west bank of the river. At several points in its southerly course the stream has reached the western border of the bottom lands of its valley, where the strong current swinging against the bordering hills has cut away the lower banks and left escarpments several hundred yards long and thirty or forty feet high. Here may be seen sandstones interbedded with shales, both arenaceous and argillaceous, containing numerous fossils probably of Pliocene age. A portion of the shale has a finely laminated structure, but much of it is massive, in this case usually containing inclusions of very hard sandstone, fossilliferous. Although land-slips have disguised the true bedding in many places, the average dip seems to be from two to ten degrees to the northeast. Several lines of sandstone boulders stand out prominently on the face of the cliff, in beds varying from a few inches to two feet in thickness, and in these the fossil contents are much better preserved than in the adjacent shales.

Fresh specimens of shale from this locality are of a grayish drab color, commonly called "blue," while the same material, when exposed on the surface or along joint lines, turns to a light brown shade, with coatings of red oxide of iron. Small amounts of alkaline sulphates are present, showing as efflorescence, but the usually common black oxide of manganese is absent. Mica, mostly muscovite, is quite prevalent, and is especially noticeable in the fine laminated structure, where the thin plates lie parallel to the cleavage of the shale. Columnar structure is sometimes shown in the thick beds of shale, the columns being four and five sided usually (with irregular forms intervening), having a diameter of a few inches only, and not much greater length. Each column is commonly coated with a layer of thoroughly oxidized material, changing in character towards the center, which may be of original "blue."

About a quarter of a mile northwest of the above locality, on hilly ground rising from the Cowlitz river, pits have been opened up in the beds, from which several thousand yards of clay have been taken by the Little Falls Clay Works. These beds apparently overlie those on the river, and their geological horizon is probably not distinct, although no connection can be traced accurately at the present time. Some difficulty is experienced in working the pits, as water accumulates in all the hollows, owing to the impervious character of the beds, and in the spring season when the whole ground is saturated, slides are frequent, bringing down the overlying gravel and debris of timber, thus covering the working face. The method of working is very simple. A level floor with a tramway is graded in the face of the hill, and the material is broken down with picks directly into cars. Nodules and boulders are thrown on the dump, along with unsuitable clay, gravel, etc. For the most part, a pick is found to be the best tool for the work on account of the easy breaking due to the joints and columns, but occasionally a large mass is loosened or thrown down with a charge of low-grade giant powder. Certain layers occur here which contain iron in such quantities as to give them a rather brilliant orange-red appearance. Some of the layers of the blue are practically unweathered and have the same appearance throughout.

Pits have been opened at other localities in this region, yielding clays of economic value. Especially good clay, both blue and white, has been obtained in the valley of the Cowlitz river, about four miles above the place described.

In the year 1891, the Washington Fire Clay Company began the manufacture of brick and pottery at Sopenah, a station on the Northern Pacific Railway, midway between Tacoma and Portland. During the years 1894–5 the works lay idle, but since that time have been running quite steadily, for the past three years under the name of the Little Falls Fire Clay Company.

A tramway nearly two miles long leads from the works to the pits described above. Owing to the grades on the line, a car carrying one and one-half tons is found to be a full load for a horse to pull. Clay has also been brought by wagon from pits further up the Cowlitz river and other points near at hand, as well as from Gale creek.

The company's works are very compact, all the manufacturing and drying being done under a single roof, while the kilns are placed under an adjoining shed. The main building is of brick, three stories high, and has an inside measurement of 80 by 250 feet, giving a total floor surface of 60,000 square feet.

As the main purpose of such a large building is to give drying room, the builders kept that idea in mind throughout its construction. The flooring is of 1½-inch stuff, set three-eighths of an inch apart, thus allowing free circulation of air from basement to roof. The heating plant, located in the basement and ground floor at the center of the west side, consists of two return tubular boilers (66 inches by 16 feet, with 56 flues apiece), connected at the bottom by a mud drum and at the top by a steam dome 28 inches by 12 feet. Two supply pipes, 1¼-inch diameter, carry live steam to two 8-inch headers, placed one in each end of the building, from which radiator pipes extend the whole length of the building, 250 feet, at intervals of six inches or less, making a total length of over seven miles of pipe. This great radiating surface serves to keep a volume of warm air circulating through the whole building aided by the spaced flooring. The drip of the dead steam returns by gravity to the boiler room and is pumped while hot into the boilers.

A 6-inch pipe supplies steam to the engine, a Nordberg Corliss, 16 by 36 inches. The main line shaft runs part way across the center of the building on the first floor. The brick presses are also on the first floor. The remainder is used as a drying floor, where the brick and tile receive their final drying before going to the kilns. Drain tile, sewer pipe and flue lining are made in a press on the second floor; the steam cylinder which furnishes the compressing power is set between floors, and the tempered clay is fed into the press on the third floor, where the screening machinery is placed. The company's office occupies the southeast corner of the second floor. On account of the fact that the drying of the pressed material must be done slowly and carefully at first, to avoid cracking, it is customary to send the products of the presses up to the third floor, farthest removed from the steam pipes, where, after two days' drying, the necessary trimming is performed.

The clay brought from the pits in tram cars, is dumped in heaps under sheds, each class by itself. It is then wheeled to the grinding pan and after being crushed is elevated to the third floor, screened through a trommel, and sent down to the mixing or wet pans.

Clay that has been mixed, screened and tempered to a proper degree of plasticity for pipe making, is elevated to the third floor and there fed to the steam press. A 4-inch pipe supplies steam at a 95 pounds pressure to a cylinder 44 by 36 inches. Under this enormous pressure the moist clay is easily forced down through the mould. For making sewer pipe a "former" is set at the bottom of the mould to form the joint head or shoulder of the pipe. Steam is let into the cylinder until the triple piston rods are forced down a few inches, filling the "former" with with clay. Next, the "former" is lowered and swung aside, steam is again admitted and enough clay is squeezed down through the mould to give a length of 29 or 30 inches to the pipe. Steam is shut off, the pipe is cut by a jack-knife folding up inside the mould, and the pipe is placed on a truck and hauled to the drying floor. The "former" is greased and swung back into position ready for another length. Four men are required to handle the pipe press, one to regulate the steam in the cylinder, one to handle the "former," and two to cut and lift off the finished pipe.

In making drain tile, or any straight pipe without a shoulder, great speed may be attained. As many as 2,500 pieces of tile of four inches inside diameter can be turned out on a single press in one day. One thousand five hundred would be a good day's run of 3-inch pipe, 1,000 for 8-inch, while in making the heavy 2-foot sewer pipe 200 pieces is about the working limit for ten hours' time. All these sizes are made on the same press, by changing the mould. After drying for two days, the pipe goes to the hands of the finisher, who cuts and fits the elbows, and trims to proper length, allowing for a shrinkage of one inch in eight, so that the burned pipe shall be two feet long. Ten days or two weeks is required for the final drying.

Paving brick which is to undergo vitrification is formed in a somewhat similar manner. A horizontal steam press forces a steady stream of clay through two moulds side by side, with opening 2½ by 4½ inches. As the stream of moulded clay issues it is cut into 9-inch lengths by means of a revolving wheel carrying pieces of fine steel wire stretched taut. An endless belt conveys the bricks to another machine where they are pressed again. Dry pressed brick is made by running rather dry clay into separate moulds, which are subjected to a high steam pressure. Special tempering is required, in order that the brick shall be stiff enough to hold a sharp edge, but will not crack on drying after being greatly compressed.

Six kilns are in use at the Little Falls works, all of them circular, 30 feet in diameter, 12 feet to the crown inside, with 10 or 12 fireplaces apiece. Down-draft is obtained by means of "bags," which direct the heat from each fire against the crown; the floor is built of spaced brick, through which the air is drawn to underground flues leading to stacks 65 feet high, one for each pair of kilns. Sewer pipe is stacked in the kilns on end, three rows high, and burned for about six days. "Try-pieces" of clay are placed inside near the door, where they can be removed by taking out a plug in the door. The kiln man in charge of the burning is thus able to tell its rate of progress. At the finishing point of the burning, vitrification is caused by scattering one or two shovelfuls of salt over each fire, using about 200 pounds to a kiln. Three or four hours later the process is completed and the kiln may be opened gradually, cooling throughout in three days. Pipe that has entered the kiln in a "green" state, that is, not thoroughly dry, usually shows white streaks and blotches on its surface, and fails to vitrify.

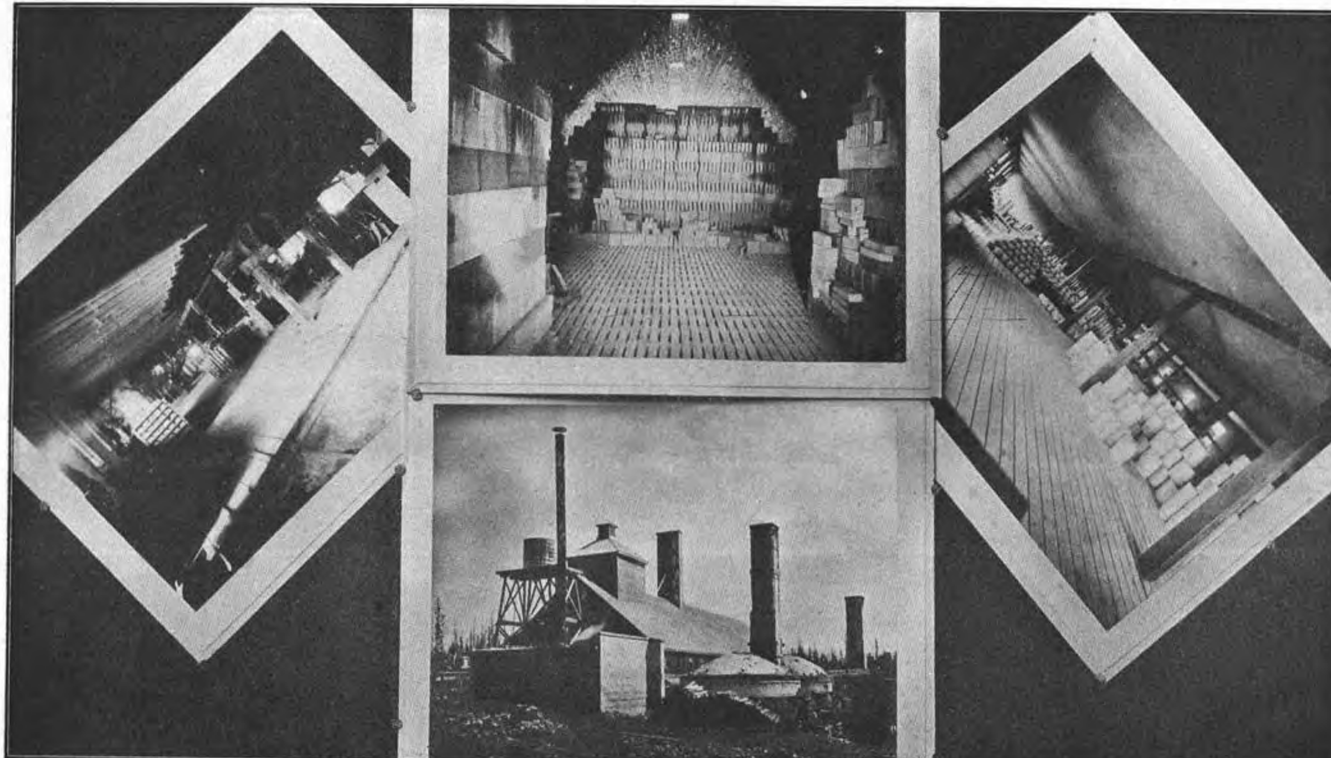
Dry pressed brick is heated slowly and burned carefully for ten or twelve days, the time varying with the character of the clay and the amount of heat it requires. Both pipe and brick attain a white heat, from which the brick will not cool in less than four days, on account of absoption due to thickness. Sections of pipe are nested, the small within the large, giving a kiln capacity of more than one thousand pieces.

The following figures showing the output of the Little Falls Fire Clay Company for the year 1901 were furnished by the manager, Mr. R. P. Bradley:

Total feet of sewer pipe, all sizes	136,196
Branches, 2-foot lengths, all sizes	3,376
Curves and elbows, all sizes	1,363
Other sewer pipe fittings, pieces	127
Feet of drain tile, 3-in. to 8-in	24,483
Paving brick	106,400
Face brick, dry press	228,500
Fire brick	10,500

WASHINGTON BRICK, LIME AND MANUFACTURING COMPANY.

Beside the plants engaged in the manufacture of common brick for the Spokane market there are several companies turn-



PLANT OF THE WASHINGTON BRICK. LIME AND MANUFACTURING COMPANY AT CLAYTON.

ing out high grade clay products whose market is not by any means confined to that immediate vicinity. The most important of these is the Washington Brick, Lime and Manufacturing Company with headquarters at Spokane and works at Springdale and Clayton, Stevens county, and at Freeman, Spokane county. The plant at Springdale is engaged in the manufacture of lime and has been described under that heading. The Clayton works, situated on the line of the Spokane Falls & Northern Railway about twenty-five miles north of Spokane, is the most important of the company's plants. There is here a fully equipped clay manufacturing plant employing seventy men, engaged in the production of common and pressed brick, architectural terra cotta, fire proofing and drain tile. The market for their product includes all the larger towns and cities of Montana, Idaho, Washington, British Columbia and Oregon. Numerous recent orders from Seattle, Boise and elsewhere have kept them running at full time. Fire proofiing and terra cotta for the new Great Northern depot at Spokane and the Masonic temple at Butte are among the most recent orders filled.

The Freeman plant, on the O. R. & N. Railway about fifteen miles southeast of Spokane, manufactures common and fire brick of superior quality. There are about forty men employed about the works. (H. Brooke.)

LIMESTONE.

INTRODUCTION.

Limestone suitable for lime-burning has been discovered at many places in Washington. It is found in a crystalline condition among the ancient rocks of the Okanogan highlands and the northern Cascades; and well-known deposits of it occur on both San Juan and Orcas islands. Wherever it is found it is wholly or partly converted into marble, and always gives evidence of much metamorphism. As a rule the limestone is a very pure calcium carbonate, although magnesium carbonate is sometimes present.

Lime belongs to that class of heavier building materials which can not stand the expense of long transportation, especially the usually heavy expense of land transportation. Lime weighs so much in proportion to its value that freight charges soon increase the price until the latter becomes prohibitive. For this reason we find a number of small kilns scattered about the state supplying the local markets, especially in the interior. Some of our lime kilns, however, are so conveniently situated in regard to cheap water transportation that they are able to supply a much more extended market and are consequently able to conduct operations on a very large scale. The lime-burning industry is more than keeping pace with the industrial development of the state along other lines. Not only are we able to supply all local demands, but we are also able to make heavy shipments to points outside the state.

SAN JUAN ISLANDS.

The San Juan islands are the center of the lime burning industry of western Washington. The principal plant on the islands, the Roche Harbor lime works, is the biggest concern of its kind in the state, if not on the Pacific coast. It manufactures more lime than all the other kilns in the state combined. Its output at the present time is about fifteen hundred barrels per day. The plant is thoroughly modern in every respect, and is under the very efficient management of Mr. John S. McMillin, the president of the company. The company has the largest deposit of pure limestone thus far discovered on the islands. It extends all the way across the peninsula from Roche Harbor to Westcott bay, a distance of half a mile. The width of the outcrop is about eight hundred and fifty feet, and the average thickness above water level two hundred and fifty feet. It extends below water level to an unknown depth. The quarry is worked from a steep face close to the water's edge and at a sufficient elevation to employ the gravity system. From the time the stone leaves its original position in the quarry until it reaches the steamer its course is always down hill. In the quarry air drills are employed in putting in the holes and giant powder is used in blasting. In work of this character the aim is of course to break as much rock as possible with each shot irrespective of its fineness or coarseness. The stone as it is blasted loose rolls to the bottom of the slope where the larger pieces are broken with a hammer; the finely broken stone is next loaded onto iron dump cars which are then run down an incline track to the chutes above the kilns. The stone is then dumped into chutes each one of which communicates with the upper opening to a kiln. The stone is fed into the kiln from above as fast as the burned lime is drawn off from the bottom. The fires are never allowed to go out except when it becomes necessary to reline the furnaces, which does not occur very often. Each kiln holds thirty tons of rock.

The length of time required to turn limestone into lime depends on the intensity of heat generated in the furnace. The kilns are of the Monitor pattern, consisting of two inner layers of fire brick, an outer layer of ordinary red brick and a sheeting or jacket of boiler iron riveted together. Between the outer layer of brick and the jacket there is a space of about two inches filled with ashes and small pebbles to act as a non-conductor of heat and also to relieve the iron jacket from the strain caused by the expansion of the bricks due to the intense heating of the interior. Each kiln is fired by two furnaces, one on each side, and consumes about a cord and a half of wood each day. Each kiln is surmounted by a smokestack of boiler iron. These increase the draft and so cause a more nearly perfect combustion of the fuel. By increasing the intensity of the heat the smokestacks reduce the time necessary to burn the lime and thus add to the capacity of the plant. Underneath the firebox there is a cooling receptacle into which the lime falls after it has become thoroughly burned. There is a system of cold air drafts in the cooler which carries off all the dust and gases and greatly hastens the process of cooling. From the cooler the lime is drawn through a chute directly into barrels of a capacity of two hundred pounds each. The barrel stands on a platform scale as it is being filled and when exactly two hundred pounds have been drawn the barrel is passed along and another empty one takes its place. The heads are put in the barrels by workmen skilled in the business, and from them the barrels are hauled in large trucks to the warehouse on the docks. The company always keeps a reserve stock of several thousand barrels in its warehouse with which to fill emergency orders on short notice. There is a good deep water harbor so that vessels of the largest size may come alongside of the wharf and load. The plant could not be more favorably located as far as cheap water transportation is concerned. The abundance and purity of the raw material, the unsurpassed transportation facilities, and the very efficient management are the three factors which have combined to build up this great industry. The following analysis of the limestone shows in a striking manner its exceptional purity:

	Per cent.
Silica	.25
Iron and alumina	.80
Phosphorus	.10
Carbonate of lime	98.85
	100.00

The company owns and operates its own barrel factory on the premises. Fir is the only wood employed in making the barrels and it has been found to be admirably suited for that purpose.

Besides using the limestone for the manufacture of lime the company has been shipping large quantities of the raw material to different smelters to be used as a flux in their blast furnaces. The stone for this purpose is run out of the quarry on cars and dumped into a long chute which leads directly to the scows onto which the limestone is loaded. The scows are then towed by means of tug boats to their destination.

Besides the plant at Roche Harbor there are a number of smaller plants burning lime in different parts of the San Juan group of islands. The chief drawback thus far encountered by most of them is that they cannot find large bodies of good limestone. The stone occurs only in isolated fragments embedded

ROCHE HARBOR LIME WORKS.

usually in an eruptive rock. These fragments are usually of small size, the largest thus far found being that owned by the Roche Harbor Company.

Henry Cowell & Company have a plant of two kilns located on the west coast of San Juan island, and about seven and one-half miles from Friday Harbor. The plant has a capacity of two hundred and thirty barrels per day. The kilns are built of sandstone and limestone, and lined with a double row of fire bricks. A gravity track runs from the quarry to the kilns, and from the kilns to the wharf. Most of the lime is shipped to the cities and towns of Puget Sound, and to Portland, Oregon. Occasional shipments are made to San Francisco and Hawaii.

At several places on Orcas island, notably near East Sound and Deer Harbor, small deposits of limestone occur. Along the water's edge near these lime outcrops several kilns have been built and in them considerable lime has been burned. The unexpected exhaustion of the supply of stone has caused some of the kilns to become idle. At the present time lime is being burned near Deer Harbor by two companies, one, the Eagle Lime Company, operating one kiln of 120 barrels capacity, and the other, the Island Lime Company, operating a kiln of 80 barrels capacity.

GRANITE FALLS.

Three miles east of Granite Falls, on the Everett & Monte Cristo Railway, is the quarry of the Canyon Lime and Cement Company. The property embraces a little more than twenty acres, or one full mining claim. The quarry is located alongside the railway and the stone is loaded directly onto the cars on the company's sidetrack. The quarry has been in operation for a year and a half, and from it at the present time there is being shipped about sixty tons of limestone per day. Regular shipments have been made to the Everett smelter ever since the quarry was opened. Shipments are also made to Seattle and other places. There is a first-class modern lime-kiln installed, having a capacity of one hundred barrels per day. From three to five hundred barrels of lime have already been made and shipped. An analysis of the lime gives the following constituents with the percentage of each:

	Per cent.
Silica	0.60
Iron oxide	1.15
Calcium carbonate	98.43
Magnesium	0.80

SPRINGDALE.

The Valley-Brook White Lime Works, located at Springdale, Stevens county, belongs to the Washington Brick, Lime and Manufacturing Company of Spokane. The property consists of about 640 acres of land, and the necessary equipment and machinery for the daily production of 500 barrels of lime, which is the present output. The Spokane Falls & Northern Railway passes through the property, and the sidings, switches, etc., provide cheap facilities for the loading and transportation of the lime.

Wherever the solid rock formation outcrops on the company's land it is limestone. Pits dug at different points, and cuts made where the formation does not outcrop, all show that limestone is the country rock throughout the entire tract. Analyses have been made from various outcrops of limestone with the following general results:

Calcium carbonate	96 per cent. or more.
Magnesium carbonate	3 per cent. or less.
Silica	1 per cent. or less.
Total	100 per cent.

Analyses made from one special quarry, with a view of supplying the paper mills with a high grade magnesian limestone, showed the contents given below:

Magnesium carbonate	47 per cent. and under.
Calcium carbonate	52 per cent. and over.
Silica, a trace to	1 per cent.

Shipments of the magnesian limestone were made to the Willamette paper mills, and the rock was found to be well suited to their purpose, but the freight rates would not permit of extended shipments at a profit, and so they were discontinued.

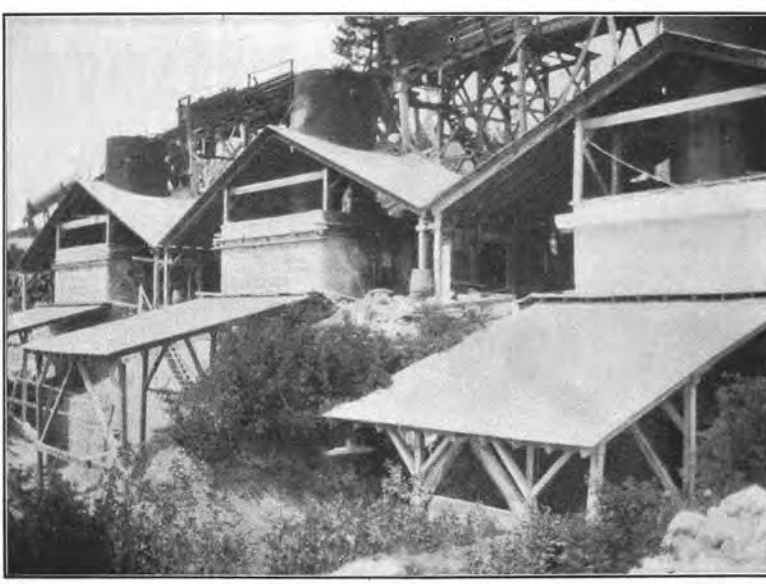
The equipment consists of four continuous kilns, capacity 500 barrels daily, track, cars, and other necessary machinery; buildings, consisting of store houses, office, residences, etc.

There is a constant and growing demand for the lime produced, but the rock carrying the high percentage of magnesium carbonate will not be in demand until paper mills or other manufactories are located sufficiently near so that freight rates will not interfere with its use, or the rates to those mills now using it are reduced.

REPUBLIC.

There is a small lime kiln between Republic and Wauconda that has produced a considerable quantity of lime for local use.

QUARRY OF THE VALLEY-BROOK LIME WORKS, SPRINGDALE.



LIME KILNS, VALLEY-BROOK LIME WORKS, SPRINGDALE.

The stone found here is a bluish, compact limestone, checked with light blue granular marble with very little spar of any sort. An analysis made by S. G. Dewsnap gave the following result:

	Per cent.
Calcium carbonate	98.2
Silica	.6
Magnesia	trace
Phosphorus	trace
Sulphur	trace
Organic matter and water	1.2
	100.00

SOILS.

GENERAL STATEMENT.

ORIGIN OF SOILS.

The rocks which form the crust of the earth are everywhere at their surface exposed to the disintegrating action of air and water. Soil is simply the decomposition product, the insoluble residue left after nearly all the soluble portion has been carried away by percolating waters. It is evident therefore that the elements which constitute the soil must have existed in some form or other in the parent rock. It does not follow, however, that the resultant soil resembles in chemical composition the rock from which it was derived, in fact analyses usually show them to be widely dissimilar. This is conspicuously the case in limestone regions where the lime in many cases has been almost entirely leached out of the soil, although forming the great bulk of the underlying rocks. In these cases the greater part of the soil is made up of constituents which formed a very small portion of the parent rock, and we must bear in mind that one foot of soil usually represents the residue left by the decomposition of a great many feet of the solid rock.

Rocks lying at any considerable distance below the surface of the earth are protected from the destructive agencies of the atmosphere, and undergo little or no alteration from these causes, but when in the course of time the rocks above them are denuded and carried away by the streams to be re-deposited somewhere else, then these underlying rocks are exposed in their turn. The agents of disintegration which exist in the atmosphere and in the soil act usually from the surface downward, so that it is always the surface of the rock which is being most attacked and any cause which increases the surface area accelerates the work of destruction. Thus the mechanical agents of air and frost which are at work breaking up the rocks act as pioneers for the chemical forces which follow them. Usually, however, most or all of these forces are working together at the same time. The agents which are at work disintegrating the rocks may be divided into two classes: 1st. Mechanical, 2nd. Chemical. Each of these may be subdivided into the forces of air, and water.

DISINTEGRATION OF ROCKS BY MECHANICAL AGENTS.

AIR.—The corrosive action of wind-blown sand in certain localities in the Middle West has carved the rocks into many fantastic shapes. This corrosive action is of course greatest nearest the ground, since most of the sand carried along by the wind is not raised far above the surface. The result is that the bases of the cliffs are continually being carved out until they become top-heavy and topple over. In comparatively arid regions like certain parts of eastern Washington where the prevailing winds are from the west or southwest, the result is shown in the form of the hills, the side exposed to the wind having its fine material carried away as fast as formed and re-deposited in more protected places. The etching effect of wind-blown sand is on the same principle as the mechanical device known as the sand blast, used in certain industries.

The rocks which form the great mass of the earth's crust are made up of a number of minerals, each having a different coefficient of expansion, so that under a change of temperature the minerals expand or contract in different degrees, thus setting up internal strains which tend to force the particles apart. The same disintegrating effect may take place in rocks of uniform texture and composition due to the unequal heating and cooling of different parts of the same rock.

WATER.—The mechanical effect of water from the soil-forming point of view is nearly all of the destructive sort. The ultimate fate of all soil is to be carried away and deposited in the sea. The material which forms the crust of the earth is continually going through a great cycle of change. It passes from solid rock to soil, is carried by the sreams down to the sea, is there deposited as sediment on the sea floor and during the succeeding ages is covered up by sediments to a depth of perhaps many thousands of feet. When these sediments have been hardened into rock, through causes little understood, they are usually elevated until they become parts of the land, and the work of erosion and deposition begins anew. We are only concerned here, however, in that stage when the rock has crumbled into soil and has not yet been carried away to the sea.

The journey of the soil from the place of origin to the sea is usually one of many stages. The soil of steep hillsides is carried away almost as fast as formed and deposited in the stream bottoms, where it accumulates often to considerable depths. Thus we have transported soil in distinction to soil that is formed in situ.

Frost is the most powerful natural agent in the mechanical disintegration of rocks. Water in passing from the liquid to the solid state undergoes a sudden increase in volume so that 100 parts of water are changed into 109 parts of ice. All rocks in their natural state are more or less saturated with moisture. When this freezes, an expansive force equal to 150 tons to the square foot is exerted tending to force the rock apart.* Any crevices which are filled with water are forced further apart when the water freezes so that the whole mass of the rock is gradually torn asunder. This force is most active on cliffs and steep hill sides where the blocks fall downward as they are riven off. Good examples of this may be seen in the talus slopes at the bottom of the basaltic cliffs bordering the stream valleys of southeastern Washington. There the frost, combined with unequal heating and cooling, has gradually wedged off and broken up the basalt into angular blocks usually of a fairly uniform size. In this particular case the cleaving action of frost seems to have stopped at a certain point, beyond which further weathering is due to chemical forces which cause the blocks to crumble into fine dirt.

DISINTERGATION OF ROCKS BY CHEMICAL AGENTS.

AIR.—There is no clear line of distinction between the chemical changes effected by water and those effected by air. The chief constituents of air by weight are nitrogen 75.66 per cent., oxygen 23 per cent. and varying small proportions of carbon dioxide and water vapor. The nitrogen is entirely inert. When the air is very dry neither the oxygen nor carbon dioxide exercise any chemical effect upon the rocks, but when moisture is present in the air they become active agents of disintegration. Among the minerals the feldspars are attacked by the carbon dioxide, and their soda, potash, and lime constituents are carried away in solution, leaving a residue of kaolin. Such minerals as pyroxene, amphibole, and mica have their iron constituents oxidized and carried off in solution.

*Geo. P. Merrill: Rocks, Rock Weathering and Soils, p. 198, New York, 1897.

A striking example of how different climates affect rocks is shown in the rapid decay of the Egyptian obelisks brought to Europe and America. During the few years since their removal in which they have been exposed to the damp, changeable climate of temperate latitudes, they have decayed more than during all the centuries in which they stood in Egypt. The dry, equable climate of Egypt affected them hardly at all.

WATER.—Absolutely pure water has very little, if any, solvent action upon the minerals composing the rocks, but pure water does not exist in nature. Meteoric waters in their passage from the clouds to the earth and into the soil take into solution a number of acids and other impurities both organic and inorganic. Water in this condition is almost a universal solvent. Its action upon the rocks from day to day is of course imperceptible, but the total effect lasting through years and centuries is very great. The chief acids in water which act as solvents are carbonic acid, humic, ulmic, and other organic acids which the water takes up in its passage through the soil. One of the principal effects of water upon the rocks is seen in the oxidation of the iron constituents of the silicates and their removal by solution, leaving the rest of the rock to crumble into dust. The most insoluble constituent of the rock-forming minerals is silica or quartz, so that it forms by far the largest proportion of the residue after the soluble portions of the rock are carried away. The higher the temperature the more active are the chemical forces and the more rapid is the disintegration of the rocks.

FERTILITY OF SOILS.

The fertility of soils is dependent upon: 1st, Chemical composition; 2d, Physical condition; 3d, Climate.

CHEMICAL COMPOSITION.

A soil in order to be fertile must contain all the elements necessary for plant nutrition in adequate proportions and in soluble form. Silica forms the great bulk of all soils. In lesser amounts are alumina, iron, magnesia, lime, potash, soda, phosphoric acid, sulphuric acid and nitric acid. The three ingredients which are essential to plant growth and which are most likely to have to be renewed are lime, potash, and phosphoric acid. Potash in the form of feldspar and phosphoric acid in the form of apatite are not available for plant nutrition because they are in an insoluble form. Where there is a large amount of lime present smaller proportions of potash and phosphoric acid are sufficient than where the lime is in lesser quantities, so that in many soils which contain potash and phosphoric acid in small quantities all that is necessary to insure permanent fertility is to add lime to the soil, usually in the form of calcium sulphate or gypsum. Nitric acid in some form is essential to plant growth. The process of nitrification changes the inert nitrogen of the air into a form whereby the plant can assimilate it.

All soil contains humus or vegetal mould in a greater or less proportion. Besides its chemical effect, it performs an important function in keeping the soil loose and porous, and thus facilitates the passage of moisture.

PHYSICAL CONDITION.

It sometimes happens that a soil rich in all the elements of fertility and blessed with a salubrious climate still obstinately refuses to yield good crops. This is due to some defect in its physical condition whereby it is unable to receive and retain the requisite heat and moisture. If the particles composing a soil are too coarse the water passes quickly through it, so that in dry weather vegetation perishes for lack of moisture. This is conspicuously the case on some of the gravel plains lying to the southward of Tacoma and Olympia. On the other hand, if the particles composing a soil are too fine it becomes caked and impervious to moisture. In this condition it is hard to cultivate and crops usually do not thrive.

CLIMATE.

In a general way it may be said that the warmer the climate the more luxuriant the vegetation, providing the moisture is adequate. Some plants require a hot growing season, but are able to stand a severe winter, while others require a more equable temperature throughout the year, so that there is no very rigid standard of comparison. Probably nowhere on the American continent is there a more striking instance of the effect of climate upon vegetation than in the state of Washington. On the western side of the Cascades the climate is very moist and there are no great extremes of heat or cold. The result is that we have here the densest vegetation of any place on the continent. East of the Cascades there are far greater extremes of temperature and the rainfall is very slight, especially in the central part of the state. The scanty vegetation is all of the desert type—sage brush, cactus and greasewood. The difference in vegetation between these two parts of the state is due mostly to the difference in the amount of rainfall, and to a much lesser extent to the greater variations of temperature in eastern Washington.

For every average temperature there is doubtless a maximum rainfall beyond which any more rain would not increase the vegetation. It is probable that this point of saturation has been reached in parts of western Washington, but it is by no means a common occurrence in tropical and temperate climates and there are probably very few places outside of the high latitudes where an increase in rainfall would not be followed by a greater luxuriance of natural vegetation.

The direct effect of winds upon vegetation is not great. Winds, however, affect temperature and rainfall most vitally. Using again as an example the difference in climate between eastern and western Washington, we find that the equable climate of western Washington is due to the warm, moist, prevailing westerly or southwesterly winds which blow off the Pacific ocean. It is well known that a large body of water is not subject to such extremes of temperature as a large body of land, so that the winds which blow off the ocean are warmer in winter and cooler in summer than those which blow off the land. The moisture laden breezes of the Pacific pass over western Washington and up the slopes of the Cascades and down into eastern Washington. By the time the Cascades are passed much of the moisture has been precipitated as rain or snow, and the air has been greatly cooled by passing over the high altitudes. It is therefore dryer and cooler.

WASHINGTON SOILS.

SOILS OF WESTERN WASHINGTON.

The soils of Washington are the result of geological conditions widely dissimilar in the different sections of the state. All of western Washington, except the southwestern part, is a region that in comparatively recent geological times, has been covered deep with glacial ice. The glaciers which filled the greater valleys of Puget sound during the geological period, came from three directions. First, there were the glaciers moving eastward from the Olympic mountains ; second, the glaciers moving westward from the Cascades ; and third, the great southward moving body of ice which came from the mountains of British Columbia, and greatly exceeded in volume the other two combined. The heterogenous mass of earth and rocks carried along by these ice streams was deposited upon the melting of the ice, and now forms the great mantle of drift which nearly everywhere covers the bed rock of the Puget sound basin. The soil formed by the weathering of this glacial material is usually quite fertile. The soil of the uplands in its virgin state supports an exceedingly heavy forest vegetation, and when this is cleared away very good farm lands are thereby produced. The bottom lands when not too swampy are exceedingly fertile, and grow in profusion all kinds of crops suitable to a temperate climate. These soils, owing to the heavy vegetation which they have supported in their unreclaimed state, are very rich in humus or vegetal mould. Here and there throughout the glaciated region there are are found lake beds, where old lakes have become entirely silted or filled up. These always have a very fertile soil, and yield excellent farms when well drained. A lake such as described once occupied the Snoqualmie valley above the falls, including the country about the present towns of North Bend and Snoqualmie.

The larger streams flowing into Puget sound have flood plains in their lower courses which contain some of the richest agricultural lands in the state. The Skagit flats and the White river valley belong in this category. The soil is a very fine silt brought down from the upper reaches of the river and deposited a thin layer at a time, during seasons of extreme high water. Like the ancient valley of the Nile the fertility of the soil is annually renewed. The silt which fills the valley of the White river has been brought down from the muddy streams flowing from the glaciers of Mt. Rainier, and like the product of all volcanic rocks, is extremely rich in the essential elements of fertility.

The giant glaciers that were mentioned above did not extend as far south as the Columbia river, so that in southwestern Washington there is a large area where the soils of the highlands are composed of the residue left by the decomposition of the rocks immediately underlying them. The rocks here are mostly sandstones and shales of the Tertiary period, capped in places by basalt. The valley soils have been washed down from the highlands and are probably nearly the same in composition but finer in texture and richer in vegetal mould.

The glacial drift of western Washington does not usually extend up the flanks of the Olympic and Cascade mountains above an altitude of two thousand feet. Above this the soils are mostly residual and comparatively thin and probably will never be of any great value for agricultural purposes.

SOILS OF EASTERN WASHINGTON.

By reference to the geological map accompanying this report it will be seen that one of the chief geological features of eastern Washington is the vast lava plain extending from the foot hills of the Cascade mountains to the eastern boundary of the state and from the Columbia and Spokane rivers on the north southward to Oregon. The rock is a basalt, very rich in minerals containing iron, lime, potash, and phosphoric acid. Everywhere in this area where the rock has decomposed sufficiently to form a soil, and the rainfall is at all adequate or water can be procured by irrigation, the land is very fertile and is rapidly being brought under cultivation. The soil of the highlands has been formed in situ and the solid rock is usually not far below the surface. Owing to the fact that the rocks below act as a reservoir for moisture and yield it up gradually during the dry months of summer a very little rainfall is sufficient.

Succeeding the period of the lava outflows there came a time in its geological history when large lakes were formed within the region now under discussion. These were finally drained, and most of the sediment which had been deposited in them has been carried away by the streams, but in some localities large areas still remain. The soil formed by the weathering of these sediments is usually of a sandy nature. It occurs in patches all along the course of the Yakima river, also in the western part of Franklin county and the southern end of Douglas county. This region is one of scanty rainfall, so that it has been found necessary to resort to irrigation in order to raise crops. Wherever this has been done the dry and barren sage-brush desert has been converted into a garden and made to support a large and thriving population.

The only cloud on the horizon which threatens the prosperity of the irrigated districts of the lava plain is the continual spreading of the alkali area. In regions of abundant rainfall the soluble salts formed from the decomposition of the parent rock are carried away in solution almost as fast as formed, but where the rainfall is scanty the water does not flow off in underground channels but rises to the surface and evaporates during the succeeding dry weather. Thus the salts instead of being carried away accumulate in the soil. They are carried upward by the ascending moisture during dry weather and upon evaporation of the moisture they form a crust or scum upon the surface of the ground. Farmers usually recognize two kinds, black alkali and white alkali. Black alkali is more injurious than white alkali. It is composed mostly of carbonate of soda, and has the power of dissolving the humus of the soil. Upon evaporation the dissolved humus leaves a dark ring about the deposit, which gives it its distinctive name. White alkali is mostly sodium sulphate and is not quite so harmful to vegetation. In the irrigated regions along the Yakima river, especially in the Kittitas and Yakima valleys, what to do with the alkali has become a serious problem to the farmer. It is only when the land has been under cultivation for a number of seasons and where it receives the drainage from land lying higher that the effects of the alkali are seriously felt. In bulletin 49 of the Experiment Station of the Washington Agricultural College and School of Science, Professor W. H. Heileman takes up the subject at length and suggests a number of remedies.

Towards the end of the Glacial period the Columbia river, together with the other streams in the northern part of the state, was charged with more sediment than it could readily carry, with the result that instead of cutting its valley deeper it kept filling it up, until the old valley was filled many hundreds of feet deep with gravel. After the ice had all gone and normal conditions again prevailed, the river carried off to the sea most of this sediment, but has left remnants all along its upper reaches in the form of gravel terraces, at various elevations above the river. Where water can be had for irrigation from the lateral streams flowing into the Columbia, these level topped terraces are cultivated. Owing to the light condition of the soil, the dryness of the climate, and the high winds which prevail, the soil is largely windblown. It is exceedingly rich and some of the finest fruit farms in the state are in this section.

Along the lower course of the Wenatche river the rocks are sandstones of Eocene age. They form, on decomposition, a light soil largely of fine sand which is easily carried about by the winds. This, mixed with glacial material brought down by the river, has formed a very fertile soil. Whenever water can be obtained for irrigation the soil yields abundantly, and up to the present time no trouble has been experienced from alkali. The general appearance of a soil gives little indication of its fertility. One can hardly conceive of any soil more barren and desolate than that which is found in many places along the Columbia river. It consists almost wholly of drifting sand, in the summer time dry as powder, and needing only the slightest puff of wind to send it whirling, yet when water is turned upon it crops grow as if by magic.

North of the Columbia lava plain, between the Columbia and Spokane rivers on the south and the international boundary line on the north there is a wide belt known in a general way as the Okanogan country. The hills are made up of granites, schists, gneisses and other crystalline rocks of ancient origin. The soil, as might be expected, differs very materially from that to the southward. These ancient rocks are composed very largely of complex silicates, such as feldspar, amphibole, pyroxene and mica. These are comparatively rich in the elements of fertility, so that we usually expect to find soil quite fertile when it is derived from such rocks. Because of the small amount of rainfall, however, nearly all of the farming that is done in this part of the state at the present time is on the terraces of the rivers where little lateral streams come in in such a manner as to afford water for irrigation. The rest of the land is given up to stockraising.

All along the eastern slope of the Cascade mountains there is a wide belt given over chiefly to pasturage. The soil is mostly formed by the disintegration of the rocks immediately below and is of at least ordinary richness, but above an altitude of about two thousand feet farming cannot be carried on successfully. Owing to the limited rainfall the timber is not heavy, and in the open glades of the forest the pasture is excellent. Large bands of cattle, sheep and horses belonging to the farmers of the lowlands are pastured here every summer.

The following analyses of Washington soils, made by Professor Elton Fulmer and Mr. C. C. Fletcher, are taken from Bulletin 13 of the department of chemistry, Washington Agricultural College and School of Science.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Insoluble residue	76.494	78.7114	78.434	75.855	28.352	69.653
Insoluble silica	62.831	65.768	60.207	66.668	21.649	69.653
Combined silica	13.663	12.943	18.227	9.187	6.703	
Soluble silica	.301	.016	.210	.033	.181	.022
Potash (K_2O)	.635	.331	.433	.008	.137	.448
Soda (Na_2O)	.374	.568	.374	.286	.191	.504
Lime (CaO)	1.081	1.512	1.213	.769	.379	.781
Magnesia (MgO)	.727	1.527	.788	.426	.036	.123
Peroxide of iron	4.554	4.610	5.158	3.587	1.055	4.823
Alumina (Al_2O_3)	7.526	5.930	6.891	6.465	4.301	8.137
Phosphoric acid (P_2O_5)	.142	.182	.101	.054	.313	.345
Sulphuric acid (SO_3)	trace	trace	trace	.038	.093	.049
Chlorine	.020	.015	.006	.007	.018	.006
Water at 120 degs. C.	4.523	2.731	3.453	3.120	11.760	3.493
Volatile and organic matter	3.612	3.745	3.019	9.160	52.874	11.613
Totals	99.992	99.881	100.79	99.808	99.691	100.00
Humus	.995	.610	.255	2.001	6.915	3.465
Nitrogen	.110	.141	.087	.234	1.347	.720

No. 1.—Typical soil of the Palouse country, taken from the college farm, Washington Agricultural College and School of Science, Pullman, Whitman county.

No. 2.—Farm of J. B. Holt, Wawaiwai, Whitman county, located on the bank of Snake river. Soil is mostly sand.

No. 3.—Sage brush soil from S. W. ¼ sec. 12 T. 14 N. R. 18 E. near North Yakima.

No. 4.—Glacial soil from Anacortes, Skagit county.

No. 5.—Typical marsh soil of western Washington from near Anacortes, Skagit county.

No. 6.—Granite soil from garden of A. L. Smith, twelve miles northeast of Spokane.

Professor Fullmer sums up his conclusions as follows:

"Barrenness may be due first, to a deficiency in lime, potash and phosphoric acid; second, to their not being in an available form, or third, to adverse climatic conditions.

"Analytical results prove that western Washington soils will be greatly strengthened by the application of lime.

"The average percentage of lime and potash are higher and phosphoric acid lower in eastern than in western Washington.

"The lime percentages are lower in regions of abundant rainfall than in the dryer parts of the state."

ROAD-MAKING MATERIALS.

GENERAL STATEMENT.

The Construction and Care of Roads.

In the pioneer stage of development a community is compelled in its road making to use the material immediately at hand whether it be good or bad. For many years to come most of our country roads necessarily will have to be made of the materials over which they run, especially the cross roads which lead off from the main highways of traffic. In the case of the larger arteries of commerce, the leading roads which bind together our towns and cities, the time is now here when the question of proper construction and of proper materials for these highways should receive the greatest attention. Road making requires skill and training of a special kind, and should therefore be done under the direction of a competent engineer. One of the greatest mistakes which is made in the laying out of roads is to require that they follow without deviation the section lines. The community should be allowed to exercise the right of eminent domain in the location of roads. It is quite as important as in the case of railroads. It is a wasteful system to require that the roads zigzag around section lines, up hill and down hill, when a comparatively level grade may be easily obtained, usually on a more direct route. It is much cheaper for a community to buy up a desirable right-of-way than it is to have its traffic for an indefinite number of years compelled to make detours and climb steep hills simply for the purpose of keeping on section lines. When permanent improvements of a road are contemplated it is especially important that the best grades and the most direct route be found, otherwise the evil is practically placed beyond remedy for many years to come.

The initial cost of good roads is usually high, and their construction should not be undertaken in a haphazard manner. America is far behind Europe in the matter of highway construction, but this is a condition of affairs which it is earnestly hoped will speedily be changed. It is said that the roads in the mountain republic of Switzerland have much more gentle grades than those of the prairie states of our own country. The system of building and maintaining roads which we use now is the same as that employed in Europe a century ago, when the roads came to be so bad that the various governments had to take the matter in hand. In England the work of constructing highways was placed in the hands of engineers like Macadam and Telford, with the result that a system of highways was built which has remained in excellent condition down to the present day. Methods similar to those employed in Europe will have to be used in this country before we can bring our highways into the same degree of excellence.

One essential thing in road construction is to have the road in such shape that it can be kept dry. The surface should be able to shed water, and ditches and culverts should be so placed that no water will be allowed to accumulate. In country districts the road should not be too wide; eight feet is usually wide enough. In making a macadam road the mistake is usually made of getting them too wide. After a road is well built care should be taken to keep it in good repair. Narrow tires on vehicles are very effective agents in destroying a road. In order to encourage the use of wide tires a number of states have offered a rebate on road taxes to all who will use them. It has been proven by a series of experiments that except in deep mud wide-tired vehicles require less power to pull them than do those with narrow tires. On a smooth hard road the advantage is found to be in favor of the wide tires. Wide tires act as road makers and narrow tires as road destroyers. The wide tires roll the road out smoothly and do not cut it into ruts.

Materials for Road Making.

For some years to come many of our roads will doubtless be made of common dirt or loam. A dirt road, if properly made and kept in good repair, has some advantages over a hard stone road in dry weather. It is not so wearing on vehicles or on the hoofs of horses. In wet weather a dirt road is the worst of all, and should be macadamized as soon as circumstances will permit. The best rock for this purpose is fine-grained volcanic rock, crushed into fragments not more than an inch and a half in diameter. This should be spread on the prepared roadbed in successive layers, each one rolled with a heavy steam roller before the next layer is spread. The topmost layer should be made of the fine dust of the broken rock. It fills up all the interstices in the layers below and cements the whole mass together.

In order to make good road material, a rock should possess considerable hardness and toughness, combined with the power of cementing well when placed in a roadbed. Granite does not make a very good macadamizing material because the quartz contained in it crumbles under the impact of traffic and the other minerals scale off and weather quite rapidly. Limestone has great cementing power, but because of its softness it does not wear as well as some other rocks. Sandstone is quite useless for macadamizing purposes as it crumbles very easily and will not cement readily. Among volcanic rocks basalt is probably the best, as it is one of the very best rocks used in road construction. It is tough, durable, and cements well.

Glacial till which has not been exposed at the surface so as to become weathered makes very good road material. It is a mixture of clay, sand and gravel, and cements together readily. Sand, when used alone, is extremely poor material to use in the construction of a road, because it will not consolidate. Clean, rounded gravel is almost as bad. A gravel bank which looks brown or red should never be used on a road. Its color shows that it has been weathered and has lost the power of cementing together when put on a road. If coarse gravel is put through a crusher, it will often cement very well on account of the fresh, unweathered surfaces exposed. Pure clay is not a good road material, but when gravel, sand and clay are mixed together they make a firm, waterproof roadway that wears very well.

ROAD-MAKING MATERIALS OF WASHINGTON.

Washington possesses a large variety of the best materials used in building roads. Not only are these materials of a superior order, but they are widespread in occurrence and practically limitless in quantity. The lack of good materials for road construction can never be urged as an excuse for poor roads in Washington. In describing the road-making materials of the state it will be possible to mention only a few of the localities where these things occur.

Western Washington.—Within the glaciated area of western Washington, which comprises all except the southwest corner of the state, glacial till occurs everywhere. A great deal of the till is good road making material. Where there is the right proportions of clay, sand and gravel with some cementing ingredient present it becomes very compact. In choosing material of this nature care should be taken to see that it is not too loose and incoherent and that it does not contain too large a proportion of clay. A bank which stands upright and when picked down falls in large masses without crumbling is the best. Within the glacial area sand and gravel are very abundant everywhere. As pointed out before, these alone are not very good for making roads. However, both are extensively used in making a foundation for vitrified brick pavements in the cities. There is a large sand and gravel plant operating at the water's edge near Steilacoom. The materials are washed and then sorted by means of revolving sieves into various grades of fineness.

Within the limits of the glacial region of western Washington, there are a number of localities where volcanic rocks suitable for macadamizing purposes crop out above the drift. Near the Port Orchard dry dock there is a quarry in basalt, near the water's edge, where rock for road building is taken out. It is crushed at the quarry and sent in scow loads to Seattle, Tacoma, and other cities about the Sound. Another quarry has been opened along the railroad track between South Seattle and Black River Junction. The rock here is mottled volcanic rock, probably andesite, and is rather too soft to be of very good quality for macadamizing. It is now being used in combination with other rocks for making concrete pavements in Seattle. Along the western side of Hoods Canal there are extensive outcrops of volcanic rock suitable for macadamizing purposes. Along the Grays Harbor branch of the Northern Pacific Railway a hard, compact, durable basalt outcrops at many places between Gate City and Aberdeen. It exists in large quantities, is very accessible, and is a road-making material of the very best quality.

At a number of places in western Washington limestone occurs which may have a large use in the road construction of the future. It is for the most part quite accessible and exists in ample quantities. Granite from Index is used very largely for street curbing in the cities about Puget Sound.

EASTERN WASHINGTON.—In eastern Washington the basalt of the great lava plans makes a first class macadamizing material. This is a part of the state which perhaps more than any other needs a system of good roads. The best farming sections of the state are located within the limits of the lava fields. In the Palouse country, about Walla Walla, and within the great bend of the Columbia, there is a large and increasing population depending upon agriculture. Wheat growing is the principal industry. During the summer months the roads are everywhere dry and in fairly good condition, but when the fall rains come and the farmer is ready to haul his grain to market the roads are usually all but impassible. When the lava finally weathers and decomposes it forms a finely powdered soil which accumulates to great depths in the valleys. When the soil becomes soaked with water there is apparently no bottom to the mud thus produced, and until it freezes or slowly dries up traffic throughout the rural districts is almost at a standstill.

A large part of the area embraced within the limits of the Columbia lava plain in this state is now so thickly populated and so prosperous that an extensive system of highway improvement should be inaugurated without any further delay. The basalt which is to be obtained everywhere makes the very best material, so that the construction of good macadamized roads would not be expensive. The rock would have to be crushed, spread in layers on the prepared road bed and rolled with heavy rollers. In this way a system of roads would be built which would be in good condition every day in the year. The saving in the expense of hauling the produce to market would more than suffice to build the roads and keep them in good repair.

North of the Columbia lava plain and east of the Cascades lies a region of ancient metamorphic rocks, granite, gneiss, schist, marble and slate with a ramifying system of trap dikes. It is a country of rolling hills given over chiefly to stock raising and mining. The towns are small and far apart, and not much in the way of a systematic improvement of the higways can be expected for some time. The trap dikes are pretty well distributed through the country rock and will furnish the very best material when the time comes to macadamize the roads. The streams all have terraces at various elevations above their beds and a great many of the roads follow along the tops of the terraces. The gravel affords a natural drainage, so that the roads are likely to be in a good condition throughout the year. In some of the more promising mining districts it is imperative that first class roads be built in order to haul the ore out and get the supplies in to the mines. Mining camps as a rule are from their nature not as permanent as agricultural communities, so that the roads do not need to be of so permanent a nature.

In the vicinity of Spokane there are wide gravel plains where the roads possess a natural drainage so that no grading or side ditches are required. These gravels are relics of the glacial period, when the Spokane river was given a bigger load than it could carry and dropped some of it by the wayside. The gravel makes an excellent foundation for the vitrified brick pavements used in the city.

In the Yakima valley the underlying rock is sandstone, belonging to the Ellensburg formation, but there is abundant basalt and other volcanic rocks near at hand for macadamizing purposes. Some of the roads in the valley have been placed in very fair condition, and travel over them is not difficult even in bad weather. If the residents of this valley continue to pursue the same enlightened policy in a few years they will have a very good system of roads.

In the Kittitas valley the geological conditions are much the same as in the Yakima valley. Ridges of basalt surround the valley on all sides, so that the rock can easily be quarried out in a hundred different places. The sandstones which occur in the vicinity of Ellensburg are not good for road-building purposes, and certainly should not be used when basalt may be had so readily.

PETROLEUM.

GENERAL STATEMENT.

Conditions of Occurrence.

Petroleum in small quantities is very widely distributed throughout the sedimentary rocks all over the surface of the globe, but, like all other economic products of nature, it is valuable only when found in a sufficiently concentrated form. The finding of oil in small amounts on the surface or in the rocks of any locality is not usually of much importance as indicating the presence of commercial quantities. Until a well has been actually sunk and large quantities of oil found, there is always a considerable element of risk no matter how favorable the surface indications may be.

Before going to the expense of drilling it is well to know just how much importance can be attached to surface indications. The presence of oil as a film on the surface of water does not count for much unless it is in large quantities. Seepages may or may not be an indication. Professor Edward Orton * says: "Along the extensive northern and western outcrops of the great Ohio shale through western New York, Ohio, Kentucky and Tennessee, oil and gas springs are everywhere found, but the supplies are invariably small in quantity, and there are no indications of storage on the large scale such as would justify the application of the term 'reservoirs' to the formation." Very often the seepages merely show that the oil has found a means of escape to the surface and that none will be found under pressure in the rocks. Besides, oil is not the only substance that forms an iridescent film on the surface of water; certain iron compounds and organic substances have the same effect. Even when the seepages of oil are unmistakable, it should be borne in mind that the presence of small quantities of petroleum in the stratified rocks is the normal condition in nature, and that it is only where the conditions are exceptionally favorable that the oil is concentrated.

*Edward Orton: Petroleum and Natural Gas. Kentucky Geological Survey, 1891.

No importance whatever can be attached to the topography of the locality as an indication of oil except where the hills and the valleys conform to the folds of the rocks. It is not likely that in the supposed oil regions of the state there is a conspicuous connection between the rock structure and the land features, so that in the absence of surface indications oil is just as likely to be found by drilling on a hill top as in a valley. Wherever possible the folds of the rocks should be determined from the surface outcroppings, and the well sunk on an anticline or arch. Since oil is lighter than water it rises to the highest part of the fold and gives place to water below. In the Pennsylvania oil fields all the successful wells are located on the arches of the folds.*

Before petroleum can accumulate in large quantities in one place three conditions are usually considered necessary. 1st. There must be a source of the petroleum; that is, there must be strata containing organic matter wherein the chemical processes may take place by which vegetal and animal tissue is changed into petroleum. 2d. There must be a reservoir of porous rock to contain the oil after it is formed. This is usually sandstone or conglomerate. In the Ohio and Indiana oil regions the reservoir is Trenton limestone. It is only when the limestone has become changed into dolomite that it becomes porous enough to act as a reservoir. Owing to local conditions in this state sandstone is most likely to act as a reservoir. 3d. There must be impervious strata above the oil-bearing beds in order to prevent the oil from escaping to the surface. Shale or other close grained rock usually occupies this position in the oil regions. To these three conditions there is usually supplemented a fourth, namely, that the rocks must be thrown into folds so that the oil can collect in the arches of the folds.

Origin of Petroleum.

Petroleum is formed by the decomposition of vegetal and animal remains embedded in the sedimentary rocks. Such rocks are formed by the accumulation of sediments on the floors of seas and lakes. Along with the inorganic sediment carried down by the streams there is always a considerable amount of organic material carried also. This material, together with the

*I. C. White: Geology of Natural Gas. Science, June 26, 1885.

remains of animals and plants which live and die in the sea, is gradually covered up by succeeding sediments. Any kind of organic matter when exposed to the air quickly decomposes, but when it is buried beneath water, and hence is very well protected from the air, decomposition goes on with extreme slowness, so that the resulting chemical products are of a different nature from those formed in the air. It is not possible to reproduce in the laboratory the conditions under which petroleum is formed; in this case we connot imitate the processes of nature. It is believed, however, by all who are recognized authorities on the subject, that oil is formed by the decomposition of organic matter contained in the sediments which have been deposited on the sea floor.

Oil has been found in nearly all the geological horizons from Silurian to late Tertiary. The Pennsylvania oil fields are in Devonian rocks, the Ohio and Indiana fields are in Silurian. The Russian oil fields, on the Caspian sea, are in Tertiary rocks. In California, where the conditions most nearly resemble those found in our own state, most of the oil is found in rocks of Miocene or middle Tertiary age. Tertiary rocks containing petroleum are known to exist all the way along the Pacific coast from South America to Alaska. In the California oil districts the rocks are sharply folded; in some of the wells the strata are almost vertical. The oil, too, is heavier than the eastern article and has an asphalt base.

PETROLEUM IN WASHINGTON.

In considering the probability of obtaining oil in Washington, it is not possible to discuss the state as a whole. Its geology is so diversified that it will have to be treated in sections. By a process of elimination, those portions of the state where the conditions do not admit of the formation and accumulation of oil will be first mentioned and set aside, until the field is narrowed to those areas where the conditions are such that oil may exist, and which may therefore afford proper prospecting ground.

Beginning with eastern Washington, the area lying between the Cascade mountains on the west and the Idaho boundary on the east, and between the Spokane and Columbia rivers on the north and Oregon on the south, forms part of the great Columbia basalt lava field. In its larger features it is approximately a level plain, but is worn locally into hills and deep canyons. In the southern part of the area the lava is several thousand feet in thickness but gradually thins out to the northward until it is not more than three or four hundred feet thick. In several places Snake river has cut its canyon down through the lava and exposed the underlying rock, which is granite. Along the Washington-Idaho boundary the lava may be seen lying directly upon old crystalline rocks. In several places in the lava field similar crystalline rocks may be seen rising above the lava in the form of hills or buttes. Steptoe butte in Whitman county is an example. On the northern and western side the lava there may also be seen overlying crystalline rocks of very ancient origin.

If oil originates from the decomposition of organic remains embedded in sedimentary rocks, as is held by all whose authority on the subject is recognized, it is clear that none need be looked for in the region just described. All the evidence goes to show that previous to the outflow of the lava the region consisted of granite, gneiss, schist, and other rocks of similar nature. Then the lava came in successive overflows and gradually submerged valleys and hills until finally the whole country was one vast level expanse of basalt. This part of the state may therefore be eliminated from the list of possible oil bearing regions.

North of the Columbia lava plain is the region known as the Okanogan highlands. It includes practically all of eastern Washington north of the Spokane and Columbia rivers. The rock is mainly of ancient crystalline type, mostly granite, gneiss, and schist, with occasional small areas of sedimentary rocks of later times. It is evident at once that it is not worth the while to look for oil in the rocks of the Okanogan highlands.

In the Cascade mountains the rocks have been folded, crushed and broken so badly that any oil which they might have held at one time has long since escaped. In the oil fields of Pennsylvania, Ohio and Indiana the evidence seems to show that a moderate amount of folding in the rocks is necessary for the accumulation of oil. When the folding and crushing have been carried to an extreme point, however, the consolidation or metamorphism of the oil bearing rock forces out the oil and it escapes through the fissures which are formed. For this reason we would also exclude the Cascade mountains from the list of places where oil is at all likely to be found.

The Olympic mountain region would be excluded for the same reason as in the case of the Cascades. This refers, of course, only to the higher parts of the mountains which are composed exclusively of igneous rocks. In the lower foothills, where sedimentary strata occur, the conditions are often favorable for oil accumulation.

This process of exclusion leaves as possible oil-bearing territory all of western Washington, with the exception of the higher parts of the Olympic mountains mentioned above. It will be seen by referring to the geological map which accompanies this report that with the exception of the San Juan islands, which are of Cretaceous age, all of the rocks embraced in the area under consideration belong to the Tertiary period. They are, therefore, of the same age as the rocks of the California oil fields.

It is probable that during Tertiary times the region now forming western Washington was the bed of a shallow sea. The Olympic mountains doubtless formed an island in this sea. Sand and mud accumulated to great depths on the sea floor, and there was buried within these sediments the remains of sea animals and plants as well as the vegetal matter brought down to the sea by the rivers. By processes known only to nature this organic matter may have been turned into petroleum just as it has been known to do under similar conditions in the great oil regions. After the sediments had accumulated to a depth of many thousands of feet and had been changed into solid rock, there came a gradual upheaval by which the sea floor was elevated until it became a part of the land. This elevation was accompanied by great lateral pressure which folded the rocks and raised the mountains to their present height. Since that time the streams have eroded away a great part of these sedimentary rocks and carried their constituents again into the sea.

During the Glacial period all but the southwestern part of this region was covered with ice several thousand feet thick. Buried within the drift material left by the glaciers are beds of vegetal matter more or less decomposed. In some instances, perhaps from this vegetal matter, a little petroleum may have been formed. If such were the case it would account for many of the so called surface indications of petroleum found in the glacial drift about Puget sound. Oil formed in glacial drift can never occur in large quantities; for this reason it is unwise to pay any attention to surface indications found in glacial material. There is usually so much clay present in the drift as to preclude any possibility of the oil having seeped from the bed rocks lying below, especially when the drift has a thickness varying from 500 to 1000 feet, as is the case in western Washington.

The best indications of oil in the state have been found along the coast between Grays Harbor and Cape Flattery. As far as known, this part of the state has never been carefully studied by a geologist, and most of the information concerning it consists of the reports brought out by prospectors and others, together with the samples of rock which they have brought along with them. Some of the specimens of rock are composed very largely of marine shells. These are of Tertiary age, probably Miocene. The rocks are mostly light colored sandstone and are considerably folded in places. They lie against the western flanks of the Olympic mountains which, from various reports, seem to be composed in large part of rocks of much more ancient origin. It is said that over wide areas the sandstone, when broken with a hammer, gives out a strong odor of oil. Clay beds strongly impregnated with petroleum are also to be found along the coast for many miles.

At least three wells are now being drilled in this part of the state. [March, 1902]. A company known as the Olympic Oil Company is drilling a well near Copalis Point, Chehalis county. They are said to be down a distance of between eight and nine hundred feet and to have good indications of oil. Another company, the Eldorado, is also drilling on Copalis river about two miles from the Olympic company's well. On the authority of Mr. George Wilkening, the president of the company, they are now down a distance of one hundred feet and are sinking as rapidly as circumstances will permit. Farther north along the coast the Lapush Oil Company is drilling a well near the little Indian village of Lapush, at the mouth of the Solduck river, in Clallam county. The rock where they are drilling is a light colored sandstone lying upon conglomerate and dipping northeast at an angle of about forty-five degrees. Good surface indications are said to be found in this neighborhood.

The work of drilling along this part of the coast is a slow process on account of the difficulty and delay in obtaining suitable tools. All drilling tools have to be obtained from San Francisco, and vexatious delays have been the rule.

Between Tenino and Grand Mound, in Thurston county, the Puget Sound Petroleum Company have reached a depth of about a thousand feet, and are still continuing operations. The Pacific Oil Wells Company of Tacoma sunk a well at Tacoma and another at Des Moines, King county, but finally abandoned both. They are now drilling a third well at Happy Valley, near Fairhaven, Whatcom county. They are now down a distance of one thousand feet and still drilling. They claim to have passed through three layers of oil-bearing sand and at the depth of about nine hundred feet to have pumped up a small quantity of oil. For the first one hundred feet the drill passed through glacial drift, but since that the formation has been mostly sandstone and shale. A company known as the Seattle and King County Oil Company are drilling a well near South Park on the western side of the Duwamish valley. They have been hindered by a number of accidents and delays, but are still sinking and at last reports had attained a depth of seven hundred feet without having found as yet any indications of oil.

This completes the list of companies which are carrying on active operations in the state, as far as known. A well was sunk near Stanwood station, Snohomish county, about ten years ago, by Mr. John E. McManus. A depth of about nine hundred feet was attained, but owing to difficulties of drilling it was finally abandoned. Other wells have no doubt been sunk at different places, but the data regarding them is not at hand.

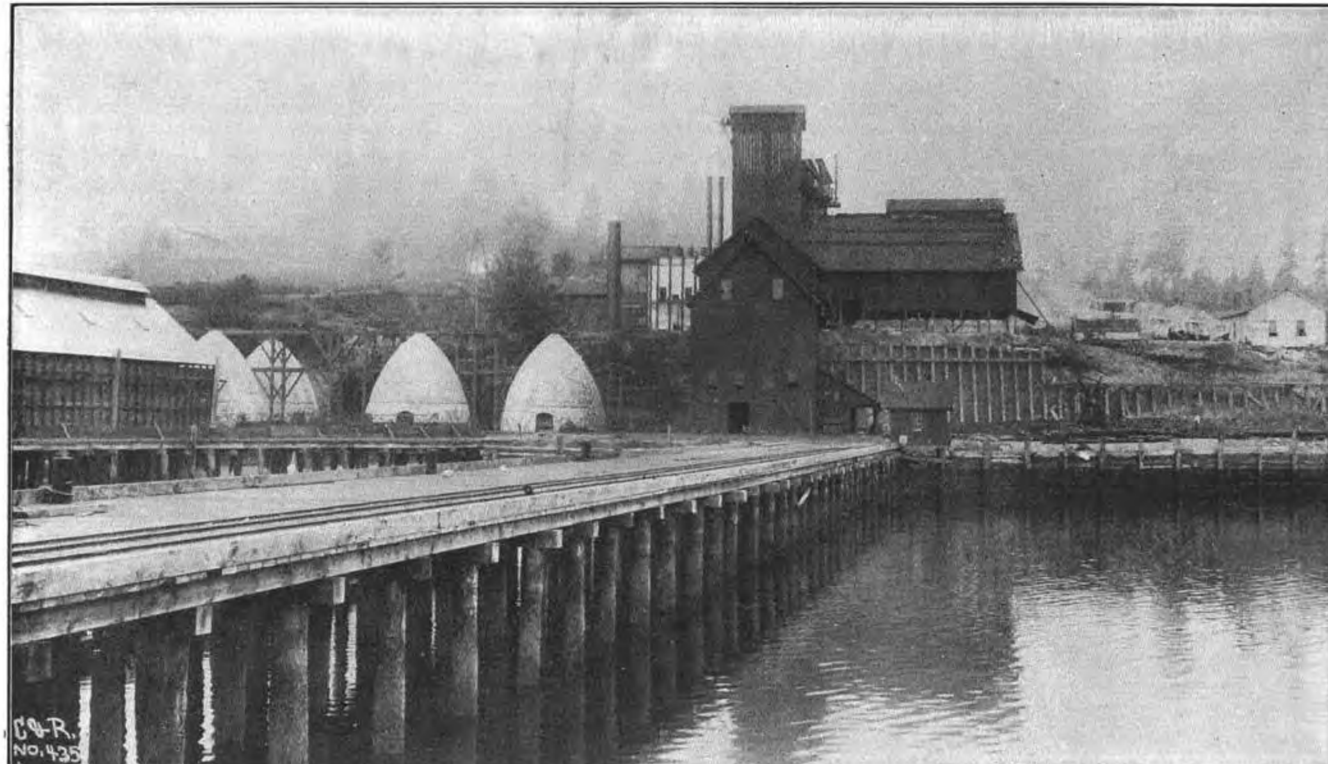
PART IV.

THE IRON ORES OF WASHINGTON.

By S. SHEDD.

THE COAL DEPOSITS OF WASHINGTON.

By HENRY LANDES.



PLANT OF PACIFIC STEEL COMPANY, IRONDALE.

THE IRON ORES OF WASHINGTON.

BY S. SHEDD.

NOTE.—The work of preparing this report on the iron ores of Washington was begun in the summer of 1899, under the direction of the Board of Regents and the president of the Washington Agricultural College and School of Science, and the entire expense, for the work, has been defrayed by the College. The summer of 1899 and a part of the summer of 1900 was spent in the field visiting the different localities, collecting samples, and studying the different deposits. The analyses of the Washington ores given herein, with the exception of those taken from a manuscript report by R. H. Stretch, E. M., and one from Willis and Smith's paper on the Clealum district, were made by myself or by the chemists of the department of chemistry in the Washington Agricultural College and School of Science.

While I take sincere pleasure in acknowledging the kind and ready assistance rendered me by those upon whom I had occasion to call for help or information of any kind, I am especially under obligations to Messrs. Thomas Cooper, J. J. Conner, Chas. Denny, and H. L. Blanchard for the interest shown and the help given, and I desire to express to them, especially, my most hearty thanks and appreciation of their kindness.

DISTRIBUTION AND COMBINATIONS IN WHICH IRON OCCURS.

GENERAL STATEMENT.

Iron is one of the most widely distributed of all the different minerals. It seldom occurs in the native state, but is combined with different elements, oxygen being the most common one, and in this form it is a very important factor in giving the color to the various rocks and soils. It combines with sulphur to form sulphides and is then known as iron pyrites and in this form it is very important, not for the manufacture of iron, but from the fact that it frequently carries more or less of the precious metals, such as gold and silver. Iron is also found in combination with other elements, such as phosphorus, silica, titanium, arsenic, etc.

THE ORES OF IRON.

While iron occurs in combination with many different elements, there are only a few forms that are used in the manufacture of iron. The valuable ores commercially are the magnetites, the hematites, the limonites, and the carbonates.

Magnetite is an anhydrous oxide of iron and when perfectly pure has the following per cent. of iron and of oxygen: Magnetite (Fe_3O_4) metallic iron, 72.4 per cent., oxygen, 27.6 per cent.

While theoretically magnetite should contain 72.4 per cent. of iron, practically very little of it does contain so high a per cent. on account of the impurities that occur with it. The common impurities are such minerals as quartz, feldspar and hornblende. Magnetites always give a black streak and differ in this respect from the hematites which have a red or brown streak. The magnetites also have the property of magnetism; that is, they are attracted by a magnet.

Of the different varieties of iron ores mined in 1899, only 1,727,430 long tons, or 7 per cent. was magnetite.*

Hematite is an anhydrous oxide of iron having, when pure, the following composition: Hematite (Fe_2O_3), oxygen 30 per cent., iron 70 per cent.

This is the most important ore of iron and is the most widely distributed of any of them, being disseminated in greater or lesser amounts in the soils and nearly all rocks; in fact most soils and rocks owe their color to iron. It is not confined to rocks of any particular geological age or to rocks of any particular kind. There are several different varieties of hematite, such as specular iron, red ochres and clay iron stone, but all of these varieties when pulverized give the characteristic red powder which distinguishes them from the other oxides of iron.

"The specular variety is mostly confined to crystalline or metamorphic rocks, but is also a result of igneous action about some volcanoes, as at Vesuvius. Many of the geological formations contain the argillaceous variety of clay iron stone, which is mostly a marsh formation, or a deposit over the bottom of shallow, stagnant water; but this kind of clay iron stone, that giving a red powder, is less common than the corresponding variety of limonite." (Dana, Edward S.: Text Book of Mineralogy, p. 335.)

In 1899 there was mined in the United States 20,004,399

*21st Ann. Rep. U. S. Geol. Survey, Part VI, Min. Res., p. 33.

long tons of red hematite, which is 81 per cent. of all the iron ore mined in the United States that year.*

Limonite, or brown hematite, is a hydrous oxide of iron having the following composition: Limonite ($2\ Fe_2O_3$, $3\ H_2O$) oxygen 25.7 per cent., iron 59.8 per cent., water 14.5 per cent.

This ore is a secondary product, in all cases, and is derived from the alteration of other ores, minerals or rocks containing more or less iron. The variety known as bog ore is the most widely distributed, occurring in many places in the United States. It has been formed in marshy places and has been carried in solution, by streams, into these places.

This ore is very apt to contain more impurities, such as silica, clay, phosphates, oxides of magnesium and other substances of this nature than magnetite or hematite. Limonite is distinguished from the other oxides of iron by its brown color when finely powdered.

The brown hematites, in 1899, amounted to 2,869,785 long tons, or 11.6 per cent. of all the iron ores mined in the United States for that year.†

Siderite, or spathic iron, is the protocarbonate of iron and has the following composition: Siderite ($Fe\ CO_3$) carbon dioxide 37.9, iron protoxide 62.1, metallic iron 48.2 per cent.

The spathic ores are the lowest in iron of all and are least important, as shown by statistics of production for 1899, there being only 81,559 long tons mined or .33 per cent. of the iron ore produced during that year.‡

The following table, taken from the Twenty-first Annual Report of the United States Geological Survey, Part VI, Mineral Resources, page 35, gives the amount of the different classes of iron ores mined in the United States for eleven years from 1889 to 1899, inclusive, with the per cent. of each class for the eleven years and also for the last year 1899. This table is given here for comparison and shows that the most important iron ore has not been found in Washington in anything but small quantities up to the present time.

* 21st Ann. Rep. U. S. Geol. Survey, Part VI, Min. Res., p. 32.

† 21st Ann. Rep. U. S. Geol. Survey, Part VI, Min. Res., p. 33.

‡ 21st Ann. Rep. U. S. Geol. Survey, Part VI, Min. Res., p 33.

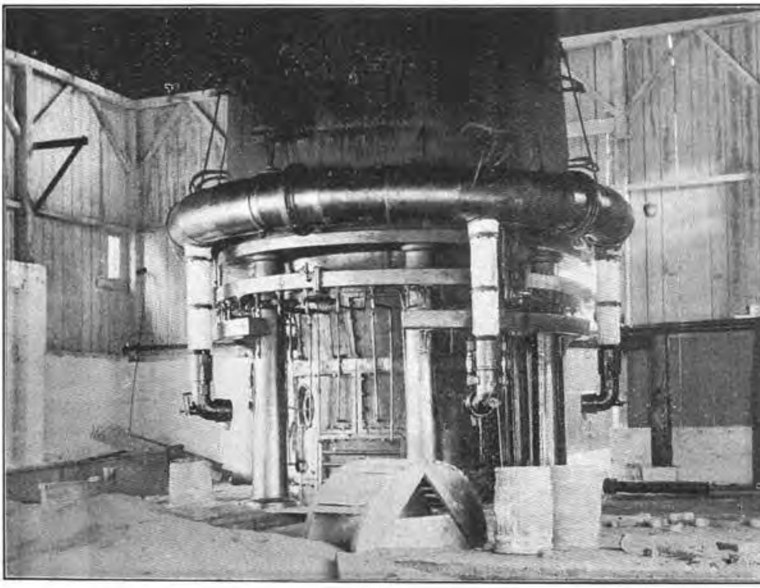
PRODUCTION OF IRON ORES IN THE UNITED STATES BY CLASSES.

YEAR.	*Red hematite, long tons.*	*Brown hematite, long tons.*	*Magnetite, long tons.*	*Carbonate, long tons.*	*Total, long tons.*
1889	9,056,288	2,523,087	2,506,415	432,251	14,518,041
1890	10,527,650	2,559,938	2,570,838	377,617	16,036,043
1891	9,327,398	2,757,564	2,317,108	189,108	14,591,178
1892	11,646,619	2,485,101	1,971,965	192,981	16,296,666
1893	8,272,637	1,849,272	1,330,886	134,834	11,587,629
1894	9,347,434	1,472,748	972,219	87,278	11,879,679
1895	12,513,995	2,102,358	1,268,222	73,039	15,957,614
1896	12,576,288	2,126,212	1,211,526	91,423	16,005,449
1897	14,413,318	1,961,954	1,059,479	83,295	17,518,046
1898	16,150,684	1,989,681	1,237,978	55,373	19,433,716
1899	20,004,399	2,869,785	1,727,430	81,559	24,683,173
Totals	133,836,710	24,697,700	18,174,066	1,798,758	178,507,234
Percentages of totals for eleven years	75.00	13.8	10.2	1.00	100.00
Percentages of total for 1899	81.04	11.63	7.0	0.33	100.00

THE RELATIVE VALUES OF IRON ORES.

The value of an iron ore does not depend entirely upon the amount of iron it contains, but upon the other substances, and amounts of them, found with it. The most common injurious substances are phosphorus and sulphur. There are, however, a number of other substances that occur as impurities, such as titanium, silica, alumina, calcium, and magnesia. These latter, however, can hardly be considered as injurious substances in the sense of injuring the pig iron, but rather as lowering the per cent. of iron. They also determine the fluxes needed. Sulphur and phosphorus, however, act in an entirely different way, and even a small amount of either of these injures the ore for a Bessemer pig iron.

Again its location is an important factor in determining the value of an iron ore, so that an ore may be quite high in the per cent. of iron it contains and still not be of any value, simply because it would cost too much to get it to market. Then again the nearness of fuels and fluxes come in to regulate its value. Take for instance Pennsylvania, which ranks first in the product of pig iron, producing in 1899, 6,558,878 long tons, or about one half of the entire product of the United States for that year, but which ranks fifth in the production of iron ore. This comes from the fact that, while Pennsylvania does not have as large deposits of iron ore as some of the other states, she does have very extensive beds of good coal, and it has been found cheaper,



FURNACE, PACIFIC STEEL COMPANY, IRONDALE.

CHARCOAL KILNS, PACIFIC STEEL COMPANY, IRONDALE.

as a general thing to ship the ore to the fuel than to ship the fuel to the ore.

THE HISTORY OF IRON MINING AND MANUFACTURE IN WASHINGTON.

The first furnace for the manufacture of pig iron in Washington began operation in the fall of 1880. This furnace was located at Irondale on Port Townsend bay about four miles south of the city of Port Townsend. The furnace had a daily capacity of ten tons and was a hot blast charcoal furnace. After being operated six months this furnace was found to be unsatisfactory, abandonded, torn down and a furnace with a capacity of fifty tons daily was constructed in its stead. On account of the very refractory nature of the ore being used this new furnace did not meet expectations, and after being operated for several months was reconstructed and then operated very successfully, as far as the grade of pig iron produced was concerned, about six months each year until 1891, when the furnace was closed down permanently.

The Irondale plant was first built for the purpose of using a deposit of limonite or bog ore which occurred south of there in the Chimacum valley, but the iron produced was found to be of a rather poor quality and the deposit proved to be very limited in quantity, so a magnetite found on Texada island, a British island situated in the Straits of Georgia, about one hundred and twenty-five miles northwest of Port Townsend, was mixed with the bog ore. It was found that a mixture of these two ores produced a very high grade of pig iron, but owing to the fact that there was an import duty of seventy-five cents a ton on the Texada ore, and charcoal being expensive, on account of having nothing but soft wood from which to make it, coke twelve dollars a ton, labor high, and the price of iron low, it was found to be a losing proposition, and it is claimed that every day the furnace was operated it was at a loss, and hence in 1891 it was closed down and had been allowed to go to decay until March, 1901, when Pennsylvania capital became interested in the matter and what is known as the Pacific Steel Company was formed and obtained control of the old Irondale plant for a consideration of $45,000. This new company immediately began the work of putting the plant in first class condition again and have expended about $100,000 on the property. December 15, 1901, the plant was again put in operation.

The new plant has a stack 60 feet high, 12 feet in the bosh, 6 feet on the crucible, and a capacity of about 50 tons a day. The power to drive the machinery for hoisting and crushing the ore will be furnished by a battery of four steam boilers, while large blowing engines will furnish the blast for the furnace.

At the present time ores from Texada island and from Hamilton, Skagit county, are being used. These two grades of ore are mixed in the proportion of 700 tons of Texada ore to 50 tons of Hamilton ore or about 93 per cent. Texada and 7 per cent. Hamilton. The principal flux used is limestone from the Roche Harbor lime works. The following analysis shows the composition of this limestone: Calcium carbonate, 98.32 per cent.; iron and alumina, 1.13 per cent.; silica, .44 per cent.; phosphorous, .11 per cent. In addition to the limestone a small amount of sand is used.

A little coke from Cokedale has been used, but the principal fuel is charcoal, and this is produced by the company's own charcoal plant on the premises. There are, for the burning of this charcoal, twenty kilns each 30 feet high and 30 feet in diameter at the base and holding 75 cords of wood each.

These twenty kilns will burn 180 cords of wood a day and have a total capacity of 180,000 bushels of charcoal per month. A sawmill and splitting-machine have been installed, so that the company now buys the logs and makes its own cordwood at the works. Machinery is being installed also for conveying automatically the wood to the kilns.

The ores from Texada island and from Hamilton are loaded on scows, transported to the plant and dumped into the bunkers. From the bunkers the Texada ore is hauled in small cars into the yard, where it is arranged in large heaps and roasted to get rid of sulphur and also to make it more easy to reduce in the furnace. Castings are made three times a day; that is, every eight hours. The pig iron at present is sold to the various foundries around Puget sound, Oregon and British Columbia. The company, however, expects in the near future to ship to San Francisco.

The old plant when in full operation employed altogether, in the mines, cutting wood and burning charcoal, and at the furnace, about 250 men. The new plant will employ directly and indirectly about 300 men.

There are a number of places in the state where considerable development work has been done, but the bog ores at Irondale are the only ones from which iron has been produced. From 1889 to 1892, inclusive, development work was quite vigorously pushed in the Clealum district in Kittitas county by a Scotch company who were contemplating the building of an extensive plant at Kirkland, on the shore of Lake Washington, but for some unknown reason work was stopped in 1892, and nothing has been done since.

In 1881 Mr. F. M. Guye discovered and located iron mines in the Cascade mountains, one and one-half miles northwest of Snoqualmie pass on the south fork of the Snoqualmie river. Soon after this he also found another deposit about six miles northeast of North Bend, the present terminus of the Snoqualmie branch of the Seattle & International Railroad.

Other properties have been located in the Snoqualmie pass district and some development work done, but at the present time (1901) nothing is being done toward developing any of these properties.

About 1881 iron ore was discovered by Mr. J. J. Conner, in Skagit county, near Hamilton on the Skagit river. Since that time these same deposits have been traced, and locations made, for several miles along the south bank of the Skagit river above Hamilton, and the ores occurring near Marble Mount are probably a continuation of these same Hamilton ores. Considerable development work has been done on some of the properties in this district, but no very great depth has been reached.

In 1881 two tons of the iron ore from the Hamilton district were sent to Tacoma and tests were made at the smelter there, and a company formed to build a plant at that place. In 1887 twenty tons were tested at Irondale. This ore was sent by J. J. Conner, of Hamilton.

About eleven miles northwest of Hoodsport in Mason county, a number of iron mines have been located and some development work done.

In Stevens county iron ores occur near Colville and Valley, each of which is on the Spokane Falls & Northern Railroad. At one time the deposits near Valley were being worked and the ore shipped to Tacoma to be used as a flux in the smelter located there.

THE DISTRIBUTION OF IRON ORES IN WASHINGTON.

Iron ore occurs in many places in the state of Washington, but only in a few places is there any prospect of the known deposits ever being utilized for the manufacture of iron. There may, however, be many mines located in the future that we know nothing about at present, as there is a large part of the state that has not been very thoroughly prospected as yet, and for that reason we do not know what we may have in the way of iron ore.

The principal known deposits are in the following counties; Skagit, King, Kittitas, Stevens, and Mason.

Bog ores are found in a number of places in the following counties; Whatcom, Clallam, Spokane, Whitman, Thurston, and Jefferson.

ANALYSES OF WASHINGTON IRON ORES.

No.	Locality.	Iron	Silica (SiO_2)	Phosphorus (P)	Sulphur	Insoluble residue	Alumina (Al_2O_3)	Manganese (Mn_2O_3)	Calcium ($CaCO_3$)	Analyzed by
	Olympic Mountains, Mason county—									
1..	Ore from cabins	16.34	....	0.13	....	24.20	8.00	27.14	11.28	Fulmer.
2..	Pomeroy mine	19.25	....	Trace.	....	70.50	.65	.32	1.13	"
3...	Pomeroy mine	4.13	....	0.21	....	19.04	6.91	42.58	6.00	"
4 .	Pomeroy mine, 4,000 feet above river	10.66	....	0.16	....	27.39	2.33	5.18	49.16	"
5..	Hoodsport mine	10.20	....	0.16	....	11.64	1.24	1.58	70.34	"
6..	Hoodsport mine	13.76	....	0.20	....	29.35	....	4.18	36.91	"
	British Columbia—									
7..	Texada island	67.91	2.96	Trace.	....	....	....	....	1.05	"
	Black Hills, Chehalis county—									
8..	Float	52.31	....	"	....	1[illegible].04	1.06	.14	....	"
9..	Float	48.18	....	....	....	25.02	.20	.23	....	"
10..	Black sand	43.72	....	....	....	24.14	11.65	.18	....	"
	Hamilton District, Skagit county—									
11..	From tunnel on Inaugural	43.89	19.98	.11	....	....	3.30	12.30	3.98	Thatcher.
12..	Hamilton mine	32.14	30.53	.31	.06	....	7.25	11.74	5.82	"
13..	Hamilton mine, near middle of vein	36.72	20.24	Trace.	....	....	7.40	13.04	9.77	"
14..	Inaugural mine, surface	31.08	31.82	.18	....	....	6.79	14.28	5.83	"
15..	Hamilton, near wall	33.88	32.94	1.06	.16	....	2.57	7.31	8.81	"
16..	Inaugural	43.91	18.36	.69	....	....	3.09	12.00	8.92	"
17..	Treadwell mine	43.72	22.85	.44	....	....	3.17	8.08	3.78	"
18..	Pittsburg mine	32.92	28.05	.31	....	....	8.43	8.11	8.06	"
19..	Pittsburg, upper ledge	29.11	32.46	.20	....	....	8.56	13.11	6.71	"
30..	Inaugural, from dump	39.44	20.84	.69	None.	....	3.76	3.67	8.63	Shedd.
33..	New opening	49.60	....	.59	"	27.04	None.	.19	3.95	Fulmer.
34..	Vein No. 5	42.43	24.13	.64	.25	....	9.54	Not det...	Not det...	Shedd.
	Snoqualmie Pass, King county—									
20..	Guye mine	67.13	3.60	None.	....	....	None.	None.....	None.....	"
21..	Guye mine	66.82	4.20	"	....	....	"	"	"	Fulmer.
35..	Denny mine	62.45	5.78	"	.21	....	5.34	"	"	Shedd.
36..	Denny mine	68.54	1.89	"	.25	....	.28	"	"	"

ANALYSES OF WASHIGTON IRON ORES—CONCLUDED.

No.	Locality.	Iron	Silica (SiO_2).	Phosphorus (P)	Sulphur	Insoluble residue	Alumina (Al_2O_3)	Manganese (Mn_2O_3)	Calcium ($CaCO_3$)	Analyzed by.
	Clealum District, Kittitas county—									
22..	Emerson mine	47.10	15.58	None.	None.	....	1.92	Not det...	Not det...	Shedd.
23..	Hard Scrabble mine	47.87	14.00	"	....	....	6.02	"	"	"
24..	Pebbly ore	46.24	7.50	"	Trace.	....	25.95	"	"	"
25..	Laminated ore from near Camp creek	47.10	8.70	"	"	....	12.22	"	"	"
26..	Laminated ore from near cabin	51.68	7.84	"	"	....	5.67	"	"	"
27..	Massive ore from near cabin	54.40	5.54	"	"	....	8.29	"	"	"
28..	Massive ore from Camp creek	51.13	6.94	"	"	....	14.23	"	"	"
29..	Best laminated ore from Camp creek	57.12	5.68	"	"	....	4.80	"	"	"
	Colville and Valley Districts, Stevens county—									
37..	Silver King mine	67.56	1.66	"	.38	....	None.	"	"	"
38..	Silver King mine	68.10	1.12	"	.25	....	"	"	"	"
39..	I. X. L. mine	56.58	4.49	.31	.32	....	2.00	"	"	"
40..	I. X. L. mine	50.48	14.90	.30	.32	....	2.48	"	"	"
41..	Capital mine	59.19	5.80	.16	.33	....	1.85	"	"	"
42..	Vigilant mine	58.33	3.54	.22	.21	....	3.18	"	"	"
44..	Mineral point	50.05	10.12	.20	.42	....	17.23	"	"	"
	Irondale District, Jefferson county—									
31..	Bog ore	53.67	....	1.09	Not det.	9.67	None.	.20	.95	Fulmer.
32..	Bog ore with gravel	28.48	....	.17	"	40.35	"	.92	2.10	"
	Cheney District, Spokane county—									
43..	Bog ore	35.12	16.30	.31	.19	....	10.94	Not det...	Not det...	Shedd.

THE CHARACTER AND COMMERCIAL VALUE OF THE IRON ORES OF WASHINGTON.

VARIETIES OF ORES.

The iron ores of Washington are magnetites, hematites, limonites, or hydrous sesquioxide of iron, known commercially as brown hematite, and mixtures of hematite and magnetite. The Snoqualmie pass ores are the only true magnetites while the Clealum, Hamilton and a part of the Stevens county ores are mixtures of magnetite and hematite. The Jefferson county ores, and part of the Stevens county ores, are limonites or bog ores. In several other places in the state the bog ores have been found in small quantities but they are of no commercial importance. The iron ore in Mason county is quite largely a hematite but most of it is of very little commercial value. In the Clealum district there is some quite strong lodestone ore.

COMMERCIAL VALUES.

One of the most important questions in connection with the commercial value of an iron ore is whether or not it is suited for the manufacture of Bessemer steel. This point is determined quite largely by the amount of phosphorus the ore contains, and the extreme limit has been placed at .05 per cent. for an ore that contains 50 per cent. of iron. While it is true that perhaps the question of the amount of phosphorus is one of the most important ones, it is necessary, of course, that the ore should have iron enough to make it profitable to work it and that the amount of silica, sulphur, and other impurities must be small enough so as not to injure it. The amount, however, of sulphur or silica allowable in a Bessemer ore is considerable more than that of phosphorus. It will be found by examination of the table, given on a following page, of analyses of ores from some of the different mines in the United States and Cuba that most of the ores are non-Bessemer ores. These ores, however, are used for making the commoner grades of iron but would not bring so high a price in the market as the Bessemer ores.

The accompanying table of analyses of Washington iron ores shows that they range in phosphorus from nothing to 1.09 per cent. As far as the per cent. of phosphorus is concerned a few of them, as far as other impurities also are concerned, would be classed as Bessemer ores, but the larger part would be non-Bessemer. In some cases where the silica is within the Bessemer limit there is quite a large amount of alumina and that in connection with the silica would probably exclude those ores from the Bessemer class. Some of the ores contain a high per cent. of manganese and quite a number of them have from 7 per cent. to 14.28 per cent., while in one instance as high as 42.58 per cent. was obtained so that some of these might be valuable for the manganese they contain, provided they occur in anything like large bodies.

As regards their per cent. of iron the Washington ores range from 28.48 to 68.54 per cent. In taking the samples for anlyses the intention was to get average samples, but as on all the properties, with one or two exceptions, very little work has been done, it was a difficult matter to sample systematically and I presume the analyses show the per cent. of iron to be a little above the average of the whole deposits. The analyses show that with the exception of a few samples from one particular locality, and which were known to be of no value as iron ores before the analyses were made, that very few of the ores have less than 35 per cent. of iron and quite a good many of them have from 40 to 60 per cent.

In their contents of silica the Washington ores have as wide a range as they have in their contents of iron. The table of analyses shows the silica to range from a little less than 2 to a little less than 33 per cent. The amount of silica allowable in an iron ore is determined somewhat, of course, by the amount of iron the ore contains but in a general way 15 per cent. is given as about the limit. The analyses show that quite a good many of the Washington ores contain less than 15 per cent. of silica while there are a number of them that contain more than 15 per cent. of silica. A mixture of these two grades might be made in such proportions as to keep the silica below the limit and in this way considerable at least of the ore high in silica might be used.

In their contents of sulphur the Washington ores range from nothing to .42 per cent., which is really quite low and in fact much lower than that of many other ores that find a ready market.

As shown by the analyses a number of the Washington ores contain a large per cent. of alumina ranging from practically none to as high as 14.23 per cent. This large amount of alumina in an iron ore is very uncommon and so much of it would be injurious to the ore.

SUMMARY.

The above facts show the iron ores of Washington, as far as their commercial value is concerned, to be principally non-Bessemer, but a few of them are Bessemer in qualitity. In iron they vary from 28.48 to 68.54 per cent.; in silica they vary from 2 to 33 per cent.; in alumina some of them run as high as 14.23 per cent.; in sulphur they are usually low; a few of them contain considerable manganese. The alumina and silica would have about the same effect or require about the same treatment, and taking the two together in some of the ores the per cent. would be very high.

The following table, taken from Vol. 1 of the Annual Report of the Arkansas Geological Survey for 1892, p. 15, comprising a number of analyses of iron ores from well know mines in the United States and Cuba, is given for comparison with the analyses of Washington ores:

ANALYSES OF IRON ORES OF VARIOUS MINES IN THE UNITED STATES AND CUBA.

No.	Locality.	Kind of ore.	Iron	Silica	Phosphorus	Sulphur	Analyzed by—
1	Tilly Foster mine, Putnam county, N. Y	Magnetite	48.91	12.18	0.015	0.548	Whitfield.
2	Crown Point, Essex county, N. Y	Magnetite	63.80	....	0.030	....	Richmond.
3	Crown Point, Essex county, N. Y	Magnetite	52.25	....	0.107	....	Richmond.
4	Moriah (Post Henry) N. Y	Magnetite	62.64	....	0.908	....	Richmond.
5	Chateaugay mine, Clinton county, N. Y	Magnetite	66.00	....	0.003	....	Richmond.
6	Chateaugay mine, Clinton county, N. Y	Magnetite	52.47	18.44	0.029	0.05	————
7	Andover mine, Sussex county, N. J	Magnetite	36.91	21.86	0.022	2.527	Blair.
8	Andover mine, Sussex county, N. J	Magnetite	62.31	....	0.001	0.059	Blair.
9	Hackelbarney mine, Morris county, N. J	Magnetite	48.38	....	0.057	0.529	Chauvenet.
10	Cornwall mine, Lebanon county, Pa	Magnetite	64.90	3.98	0.014	0.071	McCreath.
11	Cornwall mine, Lebanon county, Pa	Magnetite	57.05	8.65	0.007	2.531	McCreath.
12	Cornwall mine, Lebanon county, Pa	Magnetite	51.45	12.27	0.010	2.459	McCreath.
13	French creek, Chester county, Pa	Magnetite	56.13	....	0.040	....	Whitfield.
14	Hecla furnace, Lawrence county, Ohio	Siderite	33.29	....	0.144	....	King.
15	Monroe furnace, Jackson county, Ohio	Limonite	49.32	....	0.145	....	King.
16	Dover & Co., Amhurst county, Va	Specular and magnetite	48.47	21.58	0.103	0.352	Gorch.
17	Panic furnace, Smyth county, Va	Limonite	46.61	11.47	0.125	0.056	Gorch.
18	Cranberry, Mitchell county, N. C	Magnetite	32.37	29.99	0.010	0.128	Pitman.
19	Cranberry, Mitchell county, N. C	Magnetite	44.08	....	0.007	0.128	Pitman.
20	Penn. furnace, Greenup county, Ky	Limonite	54.39	....	0.167	....	King.
21	Shepherd bank, Lawrence county, Ky	Carbonate	40.61	14.37	0.126	0.227	King.
22	Taylor bank, Carter county, Tenn	Limonite	49.73	13.68	0.056	0.066	King.
23	Eureka mine, Jefferson county, Ala	Fossil ore	51.25	16.59	0.219	0.139	White.
24	Eureka mine, Tuscaloosa county, Ala	Limonite	46.59	15.07	0.179	0.318	White.
25	Shelby mine, Shelby county, Ala	Limonite	52.82	6.62	0.241	0.139	White.
26	Pilot Knob, Iron county, Mo	Specular ore	59.52	12.17	0.005	0.020	White.
27	Iron mountain, St. Francois county, Mo	Specular ore	64.67	....	0.019	....	King.
28	Iron mountain, St. Francois county, Mo	Specular ore	59.96	....	0.398	....	King.
29	Republic mine, Marquette county, Mich	Specular ore	67.02	3.38	0.024	0.037	Gooch.
30	Norway mine, Menominee county, Mich	Specular ore	60.20	12.43	0.047	0.043	Pitman.
31	Commonwealth mine, Marinette county, Wis	Specular ore	59.36	7.81	0.224	....	Gooch.
32	Black River Falls, Jackson county, Wis	Specular ore	37.09	....	0.047	....	King.
33	Iron mountain, Dodge county, Wis	Fossil ore	56.52	....	0.534	....	King.
34	Nipigon, Minn	Red specular ore	63.88	12.97	0.051	Trace.	————
35	Vermilion range, Minn	Red specular ore	67.17	4.61	0.083	0.020	————

ANALYSES OF IRON ORES OF VARIOUS MINES IN THE UNITED STATES AND CUBA—CONCLUDED.

No.	LOCALITY.	Kind of ore.	Iron.	Silica.	Phosphorus.	Sulphur.	Analyzed by—
36..	Marion county, Texas	Limonite	47.55	8.92	0.139	0.070	Hevendon.
37..	Cherokee county, Texas	Limonite	42.25	25.13	0.113	....	Magnenet.
38..	Llano county, Texas	Magnetite	63.74	10.08	0.018	....	——————
39..	Breece mine, Lake county, Col	Specular hematite	61.51	....	0.038	....	King.
40..	Juragua, Cuba	Magnetite	61.94	7.18	0.027	0.332	Beth. Iron Co.
41..	Juragua, Cuba	Magnetite	62.54	....	0.028	0.353	Booth, Garrett & Blair.
42..	Signa, Cuba	Magnetite	58.10	15.50	0.034	0.046	Rattle & Nye.

THE IRON MINING POSSIBILITIES OF WASHINGTON.

Conditions Necessary for Profitable Iron Mining.

As already stated, the value of an iron ore deposit depends not alone upon the quantity and quality of the ore, but also upon its position as regards fuel, fluxes, transportation and markets, as well as facilities for mining.

Conditions in Skagit County.

In Skagit county along the south bank of the Skagit river, from Hamilton to Marble Mount, occur deposits of iron ore which are very favorably situated as far as fuel, fluxes and transportation are concerned. The Seattle & Northern Railroad is built as far as Hamilton and could easily be extended if it were necessary.

There are five different veins or ore bodies in this district, ranging in thickness from 6 to 50 feet, and dipping to the south and a little to the west at an angle of 55 degrees.

The conditions for mining in this district are very favorable, as a large body of the ore occurs high up the mountain some distance above the river, so that a tunnel could be put in from down near the river and a large body of the ore mined at a minimum expense.

Just above the iron ore occurs coal which is said to be of coking quality and in large quantities, but at present (1901) nothing is being done to develop these deposits. About 12 miles west of Hamilton, at Cokedale, deposits of good coking coal occur and the coke from here could be used in connection with the Hamilton ores should it be found on further investigation that the Hamilton coals are not coking coals.

Limestone suitable for fluxes are found in close proximity to the iron ores of this locality, and a few miles east of Hamilton large quantities of limestone occur.

Conditions in Kittitas County.

The iron deposits of Kittitas county are situated about twenty miles north and a little west of Clealum on the Clealum river, a tributary of the Yakima river, in the eastern spurs of the Cascade range. This district is reached by wagon road from Roslyn, the present terminus of a short branch of the Northern Pacific Railroad, up the valley and canyon of the Clealum river.

As given by the U. S. Geological Survey, Roslyn has an elevation of 2,273 feet above sea level, and the Clealum valley, where the iron ores occur, has an elevation of 2,800 to 3,000 feet above sea level. For about 17 miles of this distance from Roslyn, or to the Salmon Lasac river, the valley has an average grade of about 20 feet to the mile, but for the rest of the distance above there, to where the iron occurs, the grade is much steeper and the canyon narrower. On the west side of the valley, opposite the iron-ore deposits, the mountains rise very abruptly to an altitude of about 6,670 feet above the sea, or 3,670 to 3,870 feet above the valley; on the east the slope is much more gradual.

Conditions in King County.

In King county magnetite occurs in the Cascade mountains at a distance of about two and one-half or three miles north and a little west of Snoqualmie pass. These ores are about twenty-eight miles from North Bend, and about fourteen miles from Martin, a station on the main line of the Northern Pacific Railroad, on the east side of the summit of the Cascade mountains. The state wagon road from North Bend through Snoqualmie pass passes within about two and one-half miles of these deposits, and the Seattle & International Railroad has been located through this pass, but at present is built only as far as North Bend.

The ore in this district is not difficult of access, but it would have to be shipped by rail to some point where fuel is convenient, as there is no coal in that locality.

Conditions in Stevens County.

In Stevens county iron-ore deposits occur in two or three localities, which have been worked and the ore shipped to the Tacoma smelter and used as a flux, but they have not been used for the production of iron.

Twenty miles north and a little east of Colville, on the head waters of Clugston creek are a number of mines which have been located as iron properties, and considerable work has been done in developing one of these locations, and a wagon road has been built to the property.

Eleven miles west and a little south of Valley, a station on the Spokane Falls & Northern Railway, is situated another body of iron ore and some mining has been done here. This district is reached by a trail, which leaves the United States Marble Company's wagon road about two miles from their quarry.

About two miles east of Valley are some more iron deposits, and these are very easy of access. These deposits were worked for several years on a small scale and the ore was brought by teams to Valley and shipped to Tacoma and used as a flux, but at present nothing is being done with these deposits.

The iron ores of Stevens county are all easy of access and the localities in which the iron occurs are well supplied with material for fluxes but lack fuel, hence the ore would probably have to be transported to some other locality in order to utilize it.

Conditions in Mason County.

About eleven miles northwest of Hoodsport, in Mason county, are deposits on which a number of locations have been made for iron. Hoodsport is a small town situated near the southern end of Hood's canal, and from this point to the iron deposits there is a good wagon road and a railway could easily be built if there was a demand for it. These deposits are about four miles above the upper end of Lake Cushman, on Boulder creek, about two hundred yards above where it empties into the Skokomish river. The country around Lake Cushman is very rough and mountainous. The mountain in which the iron ore occurs reaches an altitude of about five thousand feet above sea level and is quite steep. The ore in this district, if ever used, would have to be shipped to some other locality, as there is neither fuel nor fluxes to be found in connection with these deposits.

LAKE CUSHMAN DISTRICT.

ANALYSES OF IRON ORES FROM LAKE CUSHMAN, MASON COUNTY.

No.	Mine.	Iron.	Insoluble residue......	Phosphoric acid (P_2O_5)..	Alumina (Al_2O_3).....	Manganese (Mn_3O_4)....	Calcium ($CaCO_3$)	Analyst.......
1...	....	16.34	24.20	.13	8.00	27.14	11.28	Fulmer.
2...	....	19.25	70.50	Trace	.65	.32	1.13	"
3...	....	4.13	19.04	.21	6.91	42.58	6.00	"
4...	....	10.66	27.39	.16	2.33	5.18	49.16	"
5...	....	10.20	11.64	.16	1.24	1.58	70.34	"
6...	....	13.76	29.35	.20	......	4.18	36.91	"

The above analyses were made from what are thought to be fair samples of the deposits being prospected in this locality for iron. The analyses show that so far as iron is concerned the deposits have no value whatever. Number one and number three have considerable manganese and if they should be found in large quantities might be valuable on that account.

BLACK HILLS.

ANALYSES OF IRON ORES FROM THE BLACK HILLS, CHEHALIS COUNTY.

No.	Mine.	Iron.	Insoluble residue......	Phosphoric acid (P_2O_5)..	Alumina (Al_2O_3).....	Manganese (Mn_3O_4)....	Calcium ($CaCO_3$).....	Analyst......
8..	Float......................	52.31	13.04	Trace	1.06	.14	....	Fulmer.
9..	"	48.18	25.02	....	.02	.23	....	"
10..	Black sand	43.72	24.14	....	11.65	.18	....	"

The above analyses are from samples of float found in the Black hills and no ledges have been found as yet. Number eight has a fair per cent. of iron, but it also carries considerable titanium, and this would tend to injure it for the manufacture of iron. The samples were given me by parties in Olympia, and I know nothing about the conditions under which they were found. Numbers eight and nine looked as if they were nodules of consolidated black sand.

HAMILTON DISTRICT.

ANALYSES OF IRON ORES FROM THE HAMILTON DISTRICT, SKAGIT COUNTY.

No.	Mine.	Silica (SiO_2)...	Iron (Fe_2O_3)..	Alumina (Al_2O_3).....	Phosphorus (P_2O_5)	Sulphur........	Iron..........	Manganese (Mn_3O_4)....	Calcium ($CaCO_3$).....	Analyst.
11..	Inaugural	19.98	62.70	8.30	.25	....	43.89	12.30	3.98	Thatcher.
12..	Hamilton	30.53	45.92	7.25	.72	.06	32.14	11.74	5.82	"
13..	Hamilton	20.24	52.46	7.40	Trace	....	36.72	13.04	9.77	"
14..	Inaugural	31.82	44.40	6.79	.41	Trace	31.08	14.28	5.83	"
15..	Hamilton	32.94	48.40	2.57	2.43	.16	33.88	7.31	8.81	"
16..	Inaugural	18.36	62.73	3.09	1.58	....	43.91	12.00	8.92	"
17..	Treadwell.........	22.85	62.46	3.17	1.00	....	43.72	8.08	3.78	"
18..	Pittsburg..........	28.05	47.03	8.43	.70	....	32.92	8.11	8.06	"
19..	Pittsburg..........	32.46	41 59	8.56	.45	....	29.11	13 11	6.71	"

THE LOCATION AND MODE OF OCCURRENCE OF THE ORE.

The iron ore deposits in the Hamilton district occur on the south side of the Skagit river at Hamilton, in the western spurs of the Cascade range, about twenty-five miles above the mouth of the river. Deposits have been found as far up the river as Marble Mount, which is about twenty-five miles above Hamilton. The Hamilton deposits may be reached by the Seattle & Northern Railroad and are about fifty miles, by rail, from the tide water at Anacortes, or about twenty-five by boat by the way of the Skagit river. At Hamilton, where the iron deposits occur, the valley has an altitude, as given by the U. S. Geological Survey, of 94.56 feet above sea level, and at Marblemount, the point farthest up the river where the iron is known to occur, an elevation of 312.96 feet, making a grade for the valley from Hamilton to Marblemount of nine feet to the mile.

At Hamilton, the mountains on the south side of the valley rise abruptly from the river to an altitude above sea level of about 3,000 feet, while on the north side of the valley the ascent is more gradual. The country rock through this locality is sandstone, limestone, shales and slates. The iron ore occurs in the slates and lies parallel with the bedding.

Occurring in connection with the iron in this district, especially across the river from Hamilton, and lying above it are at least four seams of what is said to be a good grade of coal. Some work has been done on this coal, but for some reason it has been stopped and at present nothing is being done. The first vein is from 1,000 to 1,200 feet above the iron ore, and has a thickness of from 8 to 10 feet of coal with three streaks of boney matter from 1½ to 4 inches in thickness. Just below the coal is about 300 feet of sandstone, and then comes the slates in which the iron occurs. The second vein occurs about 100 feet above the first and has 6 feet of coal comparatively free from dirt. The formation between the two seams of coal is a gray sandstone with 4 feet of fire clay just below the upper vein of coal. From the second vein of coal to the third is 1,100 feet of gray sandstone. Number 3 is 3 feet thick and contains no dirt. Vein number 4 is 1,200 feet above 3, and the formation between the two is sandstone.

EXTENT OF IRON DEPOSITS.

Outcrops of iron-ore appear at intervals along the valley from Hamilton to Marblemount, a distance of about twenty-five miles. While the deposits have been found in a number or places along

IRON MOUNTAIN, NEAR HAMILTON.

INAUGURAL IRON MINE, NEAR HAMILTON.

the trend there has not been work enough done to tell definitely just what the relations of the different outcrops are to each other, but I am inclined to think they are lenses rather than veins and probably not continuous between the outcrops. The ore bodies vary in thickness from a few feet to 30 feet. From Hamilton to Birdsview, a distance of six miles, the iron ores appear at intervals on the south side of the Skagit river in five lines, one above the other, while at Marblemount only two lines of outcrops have been found so far. These outcrops trend approximately east and west and have a dip to the southwest of about 55 degrees.

CHARACTER AND COMPOSITION OF THE HAMILTON ORES.

The Hamilton ores are dark colored, massive appearing ores, having a medium specific gravity, for an iron ore, and when powdered some of them have somewhat of a reddish appearance, while others have a very dark, almost black appearance. The ores are all more or less magnetic. The reddish cast to the powder, however, shows that they contain some hematite. In places, as for instance in the tunnel on the Inaugural claim, the iron is found to be intimately mixed with a very white granular quartz, but most of the ore in the district seems to be free from this.

The following analysis, by R. W. Thatcher, shows the composition of the iron ore from the tunnel on the Inaugural mine, Hamilton district, Skagit county:

	Per cent.
Iron	43.89
Silica	19.98
Phosphorus	.11
Sulphur	......
Alumina (Al_2O_3)	3.30
Manganese (Mn_3O_4)	12.30
Calcium ($CaCO_3$)	3.98

A tunnel has been driven into the side of the mountain a distance of approximately 50 feet, to tap the iron ore on the Inaugural mine, and the sample from which the above analysis was made was taken from the face of that tunnel. In this tunnel, in places, the iron is intimately mixed with a very fine, white, granular quartz, such as was not found in any other place. The analysis shows the ore to be a little low in iron, somewhat high in silica, and quite a good per cent. of manganese, in fact enough to make a fair grade of spiegeleisen.

The following analysis, by R. W. Thatcher, shows the composition of the ore from the Hamilton mine :

	Per cent.
Iron	32.14
Silica	30.58
Phosphorus	.72
Sulphur	.06
Alumina (Al_2O_3)	7.25
Manganese (Mn_3O_4)	11.74
Calcium ($CaCO_3$)	5.82

This is an average sample from this mine and is thought to show fairly well the character of the ore taken as a whole. The analysis shows the ore to be low in iron, very high in silica and phosphorus, with some alumina and quite a high per cent. of manganese. The ore, however, taken by itself, would not be a very valuable one from which to manufacture iron.

The following analysis, by R. W. Thatcher, shows the composition of the ore from the Hamilton mine, near the middle of the vein :

	Per cent.
Iron	36.72
Silica	20.24
Phosphorus	Trace
Sulphur	......
Alumina (Al_2O_3)	7.40
Manganese (Mn_3O_4)	13.04
Calcium ($CaCO_3$)	9.77

The ore in the Hamilton mine is of two grades, that in the central part of the ore body being a little better ore than that near the outer part. In the particular places where the openings have been made, there is about 18 inches of this better grade of ore. The above analysis shows the ore to be low in iron, high in silica and manganese, with considerable alumina and calcium. The amount of manganese in this ore would, perhaps, make it of value for producing spiegeleisen.

The following analysis, by R. W. Thatcher, shows the composition of the ore from the surface of the Inaugural mine. :

	Per cent.
Iron	31.08
Silica	31.82
Phosphorus	.18
Sulphur	....
Alumina (Al_2O_3)	6.79
Manganese (Mn_3O_4)	14.28
Calcium ($CaCO_3$)	5.82

The ore from which the above analysis was made came from the surface and shows the fact that the ore, in this particular deposit at least, has increased in iron with depth while it has decreased in silica, alumina, manganese, calcium and phosphorus. This sample is low in iron, high in silica, manganese and phosphorus. The per cent. of manganese is high enough to make a fair grade of spiegeleisen.

The following analysis by R. W. Thatcher shows the composition of the ore from near the wall of the Hamilton mine:

	Per cent.
Iron	33.88
Silica	32.94
Phosphorus	1.06
Sulphur	.16
Alumina (Al_2O_3)	2.57
Manganese (Mn_3O_4)	7.31
Calcium ($CaCO_3$)	8.81

The sample from which the above analysis was made is the poorer grade of ore from the Hamilton mine and, as the analysis shows, it contains less iron, manganese, alumina and calcium and more silica, phosphorus and sulphur. The per cents. of phosphorus, sulphur and silica are so high that they preclude its being classed as a Bessemer ore. It might, however, be used in connection with a better grade of iron ore, such as the Snoqualmie pass ore, and make a good pig iron.

The following analysis by R. W. Thatcher shows the composition of the ore from the shaft of the Inaugural mine:

	Per cent.
Iron	43.91
Silica	18.36
Phosphorus	.69
Sulphur	....
Alumina (Al_2O_3)	3.09
Manganese (Mn_3O_4)	12.00
Calcium ($CaCO_3$)	8.92

The sample from which the above analysis was made was taken from a shaft that has been sunk to the depth of 85 feet on this property, and shows the character of the ore at that depth. The ore is not very high in iron but contains a high per cent. of silica, phosphorus, and manganese. In some cases, however, ores having a lower per cent., even, of iron than this one has are used.

The following analysis by R. W. Thatcher shows the composition of the ore from the Treadwell mine.

	Per cent.
Iron	43.72
Silica	22.85
Phosphorus	.44
Sulphur	....
Alumina (Al_2O_3)	3.17
Manganese (Mn_3O_4)	8.08
Calcium ($CaCO_3$)	3.78

The Treadwell mine is located near Marblemount, which is twenty-five miles above Hamilton on the Skagit river, and the ore is about the same grade as that at Hamilton. This particular sample shows the per cent. of iron to be a little low, with a high per cent of silica, phosphorus and manganese.

The following analysis by R. W. Thatcher shows the composition of the ore from the Pittsburg mine.

	Per cent.
Iron	32.92
Silica	28.05
Phosphorus	.31
Sulphur	....
Alumina (Al_2O_3)	8.43
Manganese (Mn_3O_4)	8.11
Calcium ($CaCO_3$)	8.06

The sample from which the above analysis was made came from the ore body which is situated lowest down on the hill and shows the ore to be of a very poor quality, being low in iron, high in silica and phosphorus.

The following analysis by R. W. Thatcher shows the composition of the ore from the Pittsburg mine.

	Per cent.
Iron	29.11
Silica	32.46
Phosphorus	.20
Sulphur	....
Alumina (Al_2O_3)	8.56
Manganese (Mn_3O_4)	13.11
Calcium ($CaCO_3$)	6.71

There are two ledges or ore bodies on the Pittsburg mine and the sample from which the above analysis was made came from the upper one of the two. The analysis shows the ore to be low in iron and high in silica, phosphorus, alumina, and manganese. The only redeeming feature this ore has is its high per cent. of manganese and with the very high per cent. of silica it has, it is very doubtful if it will prove of very much value to use by itself, but might be used in connection with some good high grade ore, like the Snoqualmie pass ore.

The following analysis by E. Fulmer shows the composition of the ore from a new location by J. J. Conner.

	Per cent.
Iron	46.60
Insoluble residue	27.04
Phosphorus	.59
Sulphur	Not Det
Alumina (Al_2O_3)	None
Manganese (Mn_3O_4)	.19
Calcium ($CaCO_3$)	3.95

The above analysis shows the sample to have been above the average in iron and to be very similar to the ores of this district in other respects.

The following anlysis by S. Shedd shows the composition of the ore from the upper deposits or the one just below the coal:

	Per cent.
Iron	42.43
Silica	24.13
Phosphorus	.64
Sulphur	.25
Alumina (Al_2O_3)	9.54
Manganese ($Mn_3 O_4$)	Not det.
Calcium ($Ca CO_3$)	" "

The sample from which the above analysis was made was taken from the vein highest up above the river, and while no work has been done here the analysis shows the ore to be a little above the average in the amount of iron it contains, of the ores in the Hamilton district, and in other respects to be about the same as the average ore of this locality.

SNOQUALMIE PASS DISTRICT.

ANALYSES OF IRON ORES FROM SNOQUALMIE PASS, KING COUNTY.

No.	Mine.	Silica	Iron oxide	Aluminum oxide	Phosphoric acid	Sulphur	Iron	Phosphorus	Analyst.
20	Guye	3.60	95.45	......	Trace.	......	66.81	Trace.	Fulmer.
21	Guye	4.20	95.45	......	....	......	66.82	....	Fulmer.
35	Denny	5.78	89.22	5.34	......	.21	62.45	....	Shedd.
36	Denny	1.89	97.92	.28	....	.25	68.54	....	Shedd.

THE MODE OF OCCURRENCE OF THE SNOQUALMIE PASS ORES.

The iron ores of the Snoqualmie Pass district occur on the south fork of the Snoqualmie river near the summit of the Cascade mountains.

The pass, as determined by the United States Geological Survey, has an altitude above sea level of 3,131 feet, and Guye's peak 6,980 feet and Denny mountain 5,766 feet. The ores occur in Guye's peak and Denny mountain at an altitude of from 1,500 to 2,000 feet above the Snoqualmie river. The ore appears to occur in beds or isolated masses and not in veins. The country rock in this locality is marble, limestone, granite, and conglomerate and the iron ore occurs in connection with the limestone and marble more frequently than with the other kinds of rock. In the tunnel on the Denny mine is found a coarse-grained white marble in which the particles are very loosely cemented together.

CHARACTER AND COMPOSITION OF THE SNOQUALMIE PASS ORES.

The iron ores of the Snoqualmie pass district are dark-colored heavy ores and vary from quite porous to very fine-grained masses. They have somewhat of a metallic luster, are strongly magnetic and when powdered give a black streak.

Below are given descriptions of the individual properties in Snoqualmie pass district.

THE F. M. GUYE PROPERTIES.—These properties are located on what is known as Guye's peak, about four miles northwest from Snoqualmie pass. Considerable development work has been done on these properties and some fine magnetic iron has been found here, but the question that has not been definitely settled as yet is the question of quantity. The ore here occurs in connection with marble and limestone principally.

The following analyses by Professor Elton Fulmer shows the composition of the ore from these properties:

	No. 1.	No. 2.
Iron	66.81	66.82
Silica	3.60	4.20
Phosphorus	Trace.	....
Sulphur	....	....

The analyses are of samples collected from two different localities and show the ore to be a very high grade ore almost free from phosphorus and sulphur, and as already stated, the only question that remains in connection with these deposits is the one of quantity.

THE DENNY PROPERTIES.—The Denny properties are located on what is known as Denny mountain, a high prominent peak about three and one-half miles south of Guye's peak, and about four miles southwest of Snoqualmie pass. A tunnel has been driven into the mountain for some considerable distance on these properties but nothing very encouraging has been developed. In the tunnel are exposed some very coarse-grained and poorly cemented limestones and white marbles.

The following analyses by S. Shedd show the composition of the ore from these properties:

	No. 1.	No. 2.
Iron	62 45	68.54
Silica	5.78	1.89
Phosphorus	....	....
Sulphur	.21	.25

The analyses show the ore to be excellent in quality. It is uncommonly high in iron, low in silica and sulphur, with practically no phosphorus. Number one is from the surface about fifty yards from the tunnel. The question here again is quantity, and the indications are not very favorable for any very large body of ore.

CLEALUM DISTRICT.

ANALYSES OF IRON ORES FROM THE CLEALUM DISTRICT, KITTITAS COUNTY.

No.	Mine.	Silica........	Iron oxide......	Alumina and chromium oxide........	Phosphoric acid	Sulphur........	Iron	Phosphorus....	Manganese oxide........	Analyst.
22..	Emerson	15.58	67.28	1.92	....	....	47 10	....	....	Shedd.
23..	Hard Scrabble	14.00	68.38	6.02	....	....	47.87	....	Trace	"
24..	Iron Monarch .	7.50	66.05	25.95	Trace	Trace	46.24	Trace	....	"
25..	Roslyn.........	8.70	67.28	12.22	....	....	47.10	....	.25	"
26..	Yankee........	7.84	73.83	5.67	....	....	51.68	....	.19	"
27..	Yankee........	5.54	77.71	8.29	Trace	....	54.40	Trace	Trace	"
28..	Iron Monarch .	6.94	73.02	14.23	....	....	51.13	....	Little	"
29..	Roslyn.........	5.68	86.40	4.80	....	....	57.12	....	....	"

THE MODE OF OCCURRENCE OF THE CLEALUM ORE.

The ore in this district occurs in the contact between a sandstone and serpentine as shown by Smith and Willis, in their paper read before the Washington meeting, February, 1900, of the American Institute of Mining Engineers. The ore outcrops along the valley at intervals, from about one-fourth of a mile south of Boulder creek to Camp creek, a distance of one mile and a half.

To the east of these outcrops along the river, and from 700 to 1,600 feet above them, is another line of outcrops, known as the Emerson group of mines. These have been traced for about a mile. The ore bodies are lenticular and vary in thickness from a few feet to thirty feet.

The following as regards their geological position is taken from the paper by Smith and Willis, already referred to :

"They have a definite geologic position in the rock series of the district, and their distribution is determined by the geologic structure. They lie on the surface of an extensive formation of serpentine at and in the base of a sandstone called the Swauk sandstone. The serpentine is older than the sandstone. It had been much eroded when the sandstone was deposited, and the sandstone, although composed chiefly of granite sand, contains in its lower beds, near the serpentine, bits of decomposed serpentine and heavy minerals derived from it. Limited lenses of shale composed of serpentine wash and also conglomerates of serpentine boulders occur at the base of the sandstone. Thus the surface on which the iron ores occur was an eroded surface, which, with the soil and other residual accumulations, was buried beneath granite sands. The relations and character of the ore indicate that it was a sedimentary deposit on the serpentine, was covered by the sands, and later metamorphosed to its present condition."

The nearest place to these iron deposits where coal has been found, in any quantity at least, is Roslyn, and these coals are not coking coals, so that it would seem that in order to smelt these ores it would be necessary to ship them some place to fuel or ship the coke to them, either of which would be expensive.

CHARACTER AND COMPOSITION OF THE CLEALUM ORES.

The ores of this district vary considerably in appearance and general characteristics and range from a high grade iron ore carrying 57 per cent. of metallic iron on the one hand to a serpentine on the other carrying less than 10 per cent. of iron. These ores may be separated into three classes, as follows: Massive, laminated and oolitic. The massive ore has a dull, greenish black color and when powdered gives a brownish black streak. The laminated ore varies in appearance, in some cases being dark red and in others having considerable of a metallic appearance, but in each case giving a deep red powder or streak when pulverized. The oolitic ore has a greenish black color and contains numerous oolites in an amorphous ground mass and when powdered gives a brownish black streak or powder. All of these ores are quite strongly magnetic and are apparently mixtures of hematite and magnetite. In some of the ore bodies all three classes of ore are found and in others only one class. The oolitic ore, so far as I could determine, is not found in the ore bodies farthest up on the hill, high above the river, but is quite common in those down near the river and especially those near Camp creek.

The samples from which the analyses given here were made are thought to be average samples of the ores in this district, having been selected with a great deal of care by the writer himself, and while samples could probably have been found that would have shown a higher per cent. of iron, it is thought that these samples show the average of the larger part of the ore in the district.

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CLEALUM MOUNTAIN.

GUYE IRON MINE, NEAR SNOQUALMIE PASS.

GEOLOGY OF THE CLEALUM IRON DISTRICT.

The geology of this district has been very carefully worked out by George Otis Smith and Bailey Willis of the U. S. Geological Survey, and a summary of their results has been given in a paper read at the Washington meeting, February, 1900, of the American Institute of Mining Engineers, and published in Volume 30 of their Transactions, and from that paper is taken the most of what is given here as regards the geology of the district.

Smith and Willis divide the rocks of this district into two groups and designate them as those which are older, or pre-Eocene, and post-Eocene. These two groups are unconformable, and the iron ore occurs in the contact between the two formations.

"PRE-EOCENE ROCKS.—The oldest rocks of the area are slates, chert, limestone, quartz schist, and volcanic breccias and tuffs, constituting a pre-Eocene complex. All these rocks have been somewhat metamorphosed, yet rarely too such an extent as to prevent the determination of their origin. They were folded, sheared, and intruded by igneous rocks early in the history of the region, and have been more or less mineralized with cupriferous, and argentiferous deposits.

"One of the most voluminous of the intrusives in the pre-Eocene complex consisted of large masses of peridotite, now more or less altered to serpentine. These intrusive masses are scores of miles in length and several miles in width. They have in great part the form and relation of large dikes.

"The youngest of the pre-Eocene rocks is a granodiorite closely resembling that of the Sierra Nevada. The rock looks like an ordinary medium-grained granite, except that it is poorer in quartz and slightly darker in color. It constitutes the Mt. Stuart batholith, and that mass with others in the Cascades furnished the sands of the Swauk sandstone.

"EOCENE AND POST-EOCENE ROCKS.—Arkose sandstone constitutes the great mass of Eocene strata in the Cascade range. They are of wide-spread occurrence on the west as on the east of the range. In the Mount Stuart district, the Eocene sandstones are divided by an extensive flow of basalt, and occordingly the Eocene formations are: first, the lower sandstone, which is called the Swauk; second, the Teanaway basalt; and, third, the upper sandstone, which is called Roslyn.

"The two sandstones are very similar in general character, and the eruption of basalt which flowed from conduits now represented by innumerable dikes in the Swauk sandstone, appears to have occupied a brief interval, after which the conditions of erosion and deposition were essentially the same as before it.

"The economically important facts of these Eocene rocks are the occurrence of a good grade of steam coal mined at Roslyn, and the possibly valuable iron ores at the base of the Swauk.

"The post-Eocene formations are of both sedimentary and volcanic origin. Basalt flows, younger than the Teanaway basalt, connect with basalts which form the great expanse of the Columbia plain far to the east. A complex mass of more acid volcanic rocks, chiefly andesite, occurs in intricate relations with other formations about the head waters of the Yakima river, and overlying the Swauk sandstone west of the head waters of the Clealum river, forms the summit of Goat mountain."

The following analysis by S. Shedd shows the composition of the ore from the Emerson mine.

	Per cent.
Iron	47.10
Silica	15.58
Phosphorus	....
Sulphur	....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	1.92

The analysis shows the ore from this mine to carry a fair per cent. of iron, a rather high per cent. of silica, a small amount of alumina and chromium, and no phosphorus or sulphur, and is a fairly good iron ore.

The ore body in this mine is about 30 feet wide and the walls are serpentine. The ore is of a laminated character, and different parts of the ore body would vary considerably in the amount of iron contained, but it is believed the sample analyzed would represent fairly well the average of the whole body of ore in this mine so far as the present exposures are concerned.

The following analysis by S. Shedd shows the composition of the ore from the Hard Scrabble mine.

	Per cent.
Iron	47.87
Silica	14.00
Phosphorus	.....
Sulphur	.....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	6.02
Manganese	A little

The analysis shows the ore from this property to be very similar to the Emerson, which it joins.

These properties are situated on Magnetic point at an altitude of about 1,500 to 2,000 feet above the Clealum river at Camp creek. Some work has been done on these properties and the ore bodies uncovered for some distance. The occurrence of the ore in this property is also similar to the occurrence of the ore in the Emerson.

The following analysis by S. Shedd shows the composition of the ore from the Roslyn mine:

	Per cent.
Iron	47.10
Silica	8.70
Phosphorus	....
Sulphur	....
Alumina and Chromium (Al_2O_3 and Cr_2O_3)	12.22
Manganese	.25

The analysis shows the ore to be a little low in iron, free from phosphorus and sulphur and quite high in aluminum, but at the same time it is a fair grade of ore. The ore in this mine occurs under conditions similar to those under which the ore in the Iron Monarch, which it joins, occurs. The ore body is about ten feet wide and is about half of it oolitic ore and the other half laminated ore. The sample analyzed was an average of the laminated ore, and is seen to be very similar to the oolitic ore, with the exception that it does not contain more than half as much aluminum.

The following analysis by S. Shedd shows the composition of the laminated ore from the Yankee mine.

	Per cent.
Iron	51.68
Silica	7.84
Phosphorus	....
Sulphur	....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	5.67
Manganese	.19

The analysis shows this to be a good iron ore. While it is true the per cent. of iron is not as high as it is in some iron ores, still it is above the average and then it is free from phosphorus and sulphur and does not contain a high per cent. of silica or aluminum. In this mine the oolitic ore does not occur but the laminated and massive ores do occur, and the sample was an average sample of the laminated ore. Some work has been done on this property and the samples taken were from the breast in the tunnel. The ore body in this mine is about fifteen feet wide and the laminated and massive ores are about equally divided.

The following analysis by S. Shedd shows the composition of the ore from the Iron Monarch mine.

	Per cent.
Iron	46.24
Silica	7.50
Phosphorus	Trace
Sulphur	Trace
Alumina and chromium (Al_2O_3 and Cr_2O_3)	25.95
Manganese	....

The analysis shows this sample to be a little low in iron and to contain a very high per cent. of aluminum. While the aluminum and chromium were not separated, and the per cent. of each determined, the amount of chromium is not large and will probably not exceed 5 per cent. at the outside, so that there is probably 21 per cent. at least of alumina. The sample from which the above analysis was made is what has been described elsewhere as oolitic ore of a greenish black color and made up of round grains the size of mustard seed up to as large as a pea. These grains are embedded in an amorphous or finely-crystalline ground mass. The ore body in this mine is about ten feet wide and is about half of it this oolitic ore.

The following analysis, by S. Shedd, shows the composition of the massive ore from the Yankee mine:

	Per cent.
Iron	54.40
Silica	5.54
Phosphorus	Trace
Sulphur	.....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	8.29
Manganese	Trace

The analysis shows the massive ore from this mine to carry a higher per cent. of iron than the laminated ore; it also has a higher per cent. of aluminum than the other, but not enough to interfere seriously with its smelting qualities.

The following analysis, by S. Shedd, shows the composition of the massive ore from the Iron Monarch mine:

	Per cent.
Iron	51.13
Silica	6.94
Phosphorus	.....
Sulphur	.....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	14.23
Manganese	.37

The above analysis shows the massive ore from this mine to be higher in iron and lower in alumina than the oolitic ore from the same mine.

The following analysis, by S. Shedd, shows the composition of the highest grade massive ore found in the Clealum district:

	Per cent.
Iron	5 7.12
Silica	5.68
Phosphorus	.....
Sulphur	.....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	4.80

The above analysis shows this to be a good grade of iron ore.

The following notes and analyses are from a manuscript report on the Clealum iron ores by R. H. Stretch, E. M.:

"The following is a report on eighteen sacks of ore taken at regular distances across the body with a view to get a fair sample of the quality at that point. The analyses were made by Professor Chas. F. Chandler and C. E. Pellew of Columbia college, New York.

Silica	10.28
Iron	55.08
Alumina	.60
Lime	.53
Magnesia	1.48
Manganese	.11
Phosphorus	.0139
Titanic acid	None
Sulphur	None
Carbonic acid	None
Loss on ignition	5.30
Oxygen, alkalies, etc	26.6061
	100.0000

"Another analysis of the ore tested at the Lanarkshire Steel Works, Motherwell, England, gave as follows:

Silica	5.41
Ferric oxide	57.44
Ferrous oxide	15.58
Aluminum oxide	5.31
Manganous oxide	1 65
Oxide of nickel	2.98
Oxide of cobalt	Trace
Chromium sesquioxide	2.12
Lime	Trace
Magnesia	.80
Alkali	2.49
Carbonic acid	1.90
Phosphoric acid	.161
Sulphuric acid	Trace
Combined water	3.13
	98.87
Iron	58.32
Phosphorus	.025

"The table following gives the results obtained by Dr. Edward Riley, of London, England, whose standing as a consulting metallurgist and analyst can scarcely be said to be second to that of any expert in Europe, and who is almost as well known in the United States as in his own country:

No.	Iron	Sulphur	Phosphorus	Chromium	Oxides of Ni. and Co.	Silica	Alumina	Magnesia	Lime	Oxide of Mn.
1...	49.55	Trace	Trace	2.04	1.20	7.65	9.16	3.87	Trace	1.00
2...	55.35	0.07	0.08	1.99	0.92	7.55	3.66	2.16	1.17	2.20
3...	51.66	0.05	0.02	2.06	0.90	5.85	8.30	3.26	None	0.65
4...	50.76	0.04	0.013	2.65	0.70	5.90	11.90	1.00	1.15	0.69
5...	52.26	0.04	0.016	3.18	1.10	6.10	5.40	2.75	1.25	1.15
Av.	51.916	0.04	0.0258	2.381	0.964	6.61	7.684	2.608	0.714	1.138

GENESIS OF THE ORES.

Willis and Smith, in their paper already referred to, give the following hypothesis as regards the Clealum ores:

"SOURCE OF THE IRON.—The iron concentrated in the hematite and magnetite of the ore may be of extraneous origin or derived from an adjacent rock. In the facts of its position and association, there is no evidence to show that it is a deposit brought in from any more or less remote extraneous source. There is much, on the contrary, to connect it with the serpentine. In its field relations, the ore lies on the serpentine, contains serpentine waste, and grades into shale derived from serpentine. The analysis of the ore and serpentine show that they both contain, in addition to the usual rock constituents, such occasional ones as chromium and nickel. Magnesia, an important constituent of serpentine, is also found in the ore. It is, therefore, reasonable to suppose that the iron ore is a result of concentration from the serpentine.

"CONDITIONS OF DEPOSITION.—The iron ore occurs on a surface of unconformity, the surface of the serpentine formerly exposed to the weather, and later buried under sands of the Swauk formation. In order to form a hypothesis of the conditions of concentration, it is necessary to interpret the facts of the unconformity.

"The basal-beds of the Swauk formation, other than the relatively limited occurrence of iron ore, are generally coarse arkose and more locally conglomerates, which consists of granite, greenstone and slate pebbles mixed, or of serpentine boulders alone, or rarely of granite boulders alone. The conglomates are exceedingly local in extent, and when composed almost wholly of surpentine or granite are restricted to areas of those rocks underlying. The serpentine conglomerates contain only occasionally a granite pebble or one of any other rock than serpentine. The granite conglomerates contain a larger, but yet surprisingly small proportion of slate or quartz pebbles.

"These facts, taken in connection with the enormous volume of arkose which constitutes the Swauk and Roslyn formations,indicate that the conditions limited the transportation of boulders and shingle, but favored the accumulation of granite sands, and, furthermore that the localities where serpentine was weathering were for a time protected from the widespreading deposits of arkose.

"The basal contact of the Swauk with the older formations is exceedingly uneven, and when traced out reveals the bold relief of the Eocene topographic surface, in which the soft shattered serpentine corresponded with lowlands. These depressions, which received little or no wash of other rocks than serpentine, may have been watersheds limited to areas of that rock. Here meteoric waters leached out the soluble parts of the disintegrated rock, and the mantle of residual material was deep. The climate was sub-tropic and vegetation abundant.

"As the coast of the rising water-body of the early Eocene time was established it assumed a very irregular outline, with numerous bays and promontories. The climate became favorable to very rapid disintegration of the granite, probably through slight hydration of the feldspar, without marked chemical change. At certain points along the coast, streams delivered the granite waste, which was built into beaches, spits and bars by shore currents. Behind the beaches and spits, lagoons were enclosed and, in some instances, such lagoons corresponded to shallow bays which received the drainage from areas of serpentine. That drainage was charged with iron and with decaying plants. The conditions were thus favorable for precipitation of iron either as ferrous carbonate or as a hydrate of the sesqui-oxide in the shallow water of the lagoon. As the shore line of the slowly rising water-body advanced upon the land, the several conditions advanced with it, and in favorable localities a deposit of iron was a characteristic, and more or less extensive, basal deposit of the sediments. The conditions are believed to have been closely analogous to those which accompanied the deposition of the carbonate ores that have been dug in the Cretaceous formations about Baltimore, Md.

"CHEMICAL RELATIONS.—In connection with the hypothesis that the ore is the product of decay of the serpentine, a comparison of the analyses of the two is essential. The serpentine, of which the following is an analysis, was collected at some distance from the Clealum river locality, but fairly represents the rock at that point. It is here compared with the average sample of ore taken by Mr. Willis.

	Serpentine, Per cent.	*Ore, Per cent.*
SiO_2	39.	7.5
TiO_2	Trace.	.7
Al_2O_3	1.75	21.9
Cr_2O_3	.47	2.2
Fe_2O_3	5.16	37.1
FeO	1.71	21.3
MnO	.15	Trace.
MgO	38.	2.3
H_2O	13.74	6.8
K_2O-No_2O	.10	Undet.
P_2O_5	Trace.	.09
NiO	.10	.2
S	.03	.03
CO_2	None.	.15
	100.21	100.27

"In comparing these two analyses we may consider the lean ore as a rearranged, but chemically little modified, residual product of the serpentine. In such comparisons most students of the subject of weathering have regarded alumina as the constituent least liable to removal, and therefore best adapted to serve as a basis of calculation.

"Supposing none of the alumina to have been lost in the course of the weathering of the serpentine, the alumina present in the residual product furnishes a measure of the amount of concentration involved in the process, and also of the amount of the material removed. In the present case, the alumina percentage having increased from less than two to nearly twenty-two, it would follow that twelve and one-half units by weight of the serpentine were required to furnish one unit of the residual deposit. Calculating the losses for the principal constituents it is found that the material removed has been in the main silica, magnesia and water. The approximate losses suffered by these constituents expressed in percentages are 96, 99 and 97 per cent., respectively. There is no apparent loss of ferrous iron, but in view of the probable interchanges of the two oxides of iron, the result may, perhaps, be expressed in terms of the iron itself, which shows a loss of 31 per cent. in the course of the decomposition of the serpentine into the residual product. There were also small losses of manganese, chromium, phosphorus, nickel and the alkalies, many of these losses being large if expressed in terms of the amount present in the serpentine."

The amount of concentration as here shown by Willis and Smith may seem very large and almost unreasonable but there are cases on record* where serpentine weathered into a residual soil and, based on the amount of alumina, showed a concentration of nearly thirty to one. The two cases are quite similar but differ in the fact that in the soil the amount of silica is sufficient to combine with the alumina while in the iron ore there is more than enough alumina to combine with the silica and the alumina must therefore be present in the free or uncombined condition.

From the foregoing it is plain to see that Willis and Smith attribute the Clealum iron ores to the weathering and concentration of the serpentine in which they are found at present and that they are not contemporaneous with them.

COLVILLE AND VALLEY DISTRICT.

ANALYSES OF IRON ORES FROM STEVENS COUNTY.

No.	Mine.	Silica........	Iron Oxide......	Aluminum and Chromium Oxides	Phosphorus Acid.........	Sulphur.........	Iron...........	Phosphorus......	Analyst.
37..	Silver King, Valley..........	1.66	96.51	....	....	.38	67.56	....	Shedd.
38..	Silver King, Valley..........	1.12	97.28	....	....	.25	68.10	....	"
39:	I. X. L., Colville.............	4.49	80.08	2.00	.72	.32	56.58	.31	"
40..	I. X. L., Colville.............	14.90	72.12	2.48	.68	.32	50.48	.30	"
41..	Capital, Valley...............	5.80	84.55	1.85	.36	.33	59.19	.16	"
42..	Vigilant, Valley..............	3 54	83.62	3.18	.51	.21	58.53	.22	"

THE MODE OF OCCURRENCE OF THE ORES.

The general character of the region in which the iron ores of Stevens county occur, is that of a mountainous country with comparatively level valleys of considerable extent along the larger streams and the mountains rising gradually until an altitude of from 2,000 to 3,000 feet above the valleys is reached. The rocks of this region are limestones, shales, slates, serpentines, porphyries and marbles. The ores occur both in veins and in bedded deposits principally in the limestone and porphyry.

*Merrill: Rock, Rock-Weathering and Soil, p. 226.

CHARACTER AND COMPOSITION OF THE STEVENS COUNTY ORES.

The ores of Stevens county are principally hematites and limonites, and vary in appearance and texture from a very compact metallic-appearing mass to a finely divided loose red powder which has been used very successfully as a paint. Some of these ores again have small octahedral crystals of magnetite scattered profusely throughout the mass.

The ore from the Clugston creek district is a limonite or bog ore of a porous nature and ranges in hardness from a soft decomposed ore to a hard flinty ore. When pulverized it gives a brown streak and powder. The ores east of Valley are limonites having a deep red to almost black color, and when pulverized vary in color from a brown to dark red, indicating that in some cases at least there is some hematite present. The ores from west of Valley are hematites with some magnetite and vary in appearance from deep red to metallic. These ores when pulverized give a deep red streak and powder. The ores of Stevens county carry a high per cent. of iron, running from 50 per cent. to as high as 68 per cent. metallic iron.

THE CLUGSTON CREEK DISTRICT. — This district is about twenty miles north and a little west of Colville, T. 39 N., R. 37 E., section 11. The country rock in this district is a limestone and the iron ore seems to occur in masses, and not in a continuous vein, in the limestone and varies from well concentrated iron ore to limestone with very little iron ore in it. Two tunnels have been run on one of these properties, and at the end of the lower tunnel a shaft sixty feet deep has been sunk, so that a depth of 100 to 120 feet has been reached on this property. In the upper tunnel considerable ore was found, but in the lower one and in the shaft no ore was found. The ore in this district from present indications, so far as I was able to judge, is of very limited extent.

The following analyses by S. Shedd show the composition of the ore from the I. X. L. mine:

	Per cent.	*Per cent.*
Iron	56.58	50.48
Silica	4.49	14.90
Alumina	2.00	2.48
Sulphur	.32	.32
Phosphorus	.31	.30

The analyses show the ore to carry a good per cent. of iron and not an unusually high amount of sulphur or phosphorus and to vary considerably in the amount of silica. The amount of phosphorus is too high for a Bessemer ore.

The following analyses by S. Shedd show the composition of the iron ore from the Silver King mine:

	Per cent.	Per cent.
Iron	67.56	68.10
Silica	1.66	1.12
Alumina	....	....
Sulphur	.38	.25
Phosphorus	....	....

The analyses show this ore to be a very fine high grade iron ore. The samples analyzed were both from the same property. Some development work has been done on this property, a tunnel having been run in on the ledge for about forty feet, but as the hill has a comparatively gentle slope no very great depth has been reached. The country rock is shale, slate, limestone, and serpentine. The question of quantity is one that remains to be determined, as with the amount of work done it is not possible to tell very much as to the extent of the ore body.

The following analysis, by S. Shedd, shows the composition of the iron ore from the Capital mine:

	Per cent.
Iron	59.19
Silica	5.80
Alumina	1.85
Sulphur	.33
Phosphorus	.36

The above analysis shows the ore to be a good grade iron ore, a little high in sulphur and phosphorus for a Bessemer ore, however. This property is situated about two miles east of Valley, a small town on the Spokane Falls & Northern Railroad. The ore appears to occur in a bedded deposit and varies from a soft, loose, reddish mass to a hard compact ore, occurring in more or less concretionary or nodular masses. Considerable ore has been shipped from here to the Tacoma smelter and used as a flux in the smelting of other ores.

The following analysis, by S. Shedd, shows the composition of the iron ore from the Vigilant mine:

	Per cent.
Iron	58.53
Silica	3.54
Alumina	3.18
Sulphur	.21
Phosphorus	.51

The analysis shows this sample to be a good ore as far as the per cent. of iron it contains is concerned, but, like the preceding one, to be too high in sulphur and phosphorus for a Bessemer ore. The occurrence of the ore in this mine is similar to that in the Capital. The sample analyzed was a finely divided, loose, uncompacted mass, and similar to the ores from this locality that have been used to a limited extent as a roof paint.

CONCLUSIONS.

Several things must be taken into consideration in determining the location of iron and steel industries or plants, the most important of which are the following: iron ore, fuel, fluxes, price of labor, and nearness to markets.

The preceding analyses show that Washington has some very high grade iron ores, but the question that has not been settled as yet is the one of quantity. In most of the districts of the state where iron is found so little work has been done that it is not possible to say positively whether the ore occurs in large quantities or not, and since the quality of the ore is good it would seem to be worth while to spend money enough in prospecting thoroughly some of the best districts to determine the extent of the deposits.

The Snoqualmie pass, the Clealum, and the Stevens county deposits are all situated long distances inland, and in most cases some distance from railroads. The Snoqualmie pass district, which contains the highest grade of iron ore, is about fifty miles from tide water and the Clealum district is about eighty miles, and no fuels near them except wood for charcoal. This would probably mean the paying of freight on them to tide water some place on the Sound, and unless the freight rate could be lowered very materially from what it is at the present time it would tend to prevent the using of these ores.

The question of good fuel is a very important one in the manufacture of iron and one that, so far as I can learn, has not been fully solved as yet in Washington. Charcoal makes a very high grade pig iron, but it is expensive and especially so where it has to be made from soft wood as it does here. Washington has large deposits of coal, some of which are coking coals, but the coke is not of the best quality, however, for the manufacture of iron. A good coke for iron furnaces should be low in ash, free from phosphorus and sulphur, and hard enough so as not to crush when charged into the furnaces. If it is high in ash it takes just that much more flux, as it has to be gotten rid of by this means. As already stated, a very small per cent. of phosphorus or sulphur in a pig iron injures it for many purposes. If the fuel contains these substances they show in the pig iron the same as though they had been in the ore.

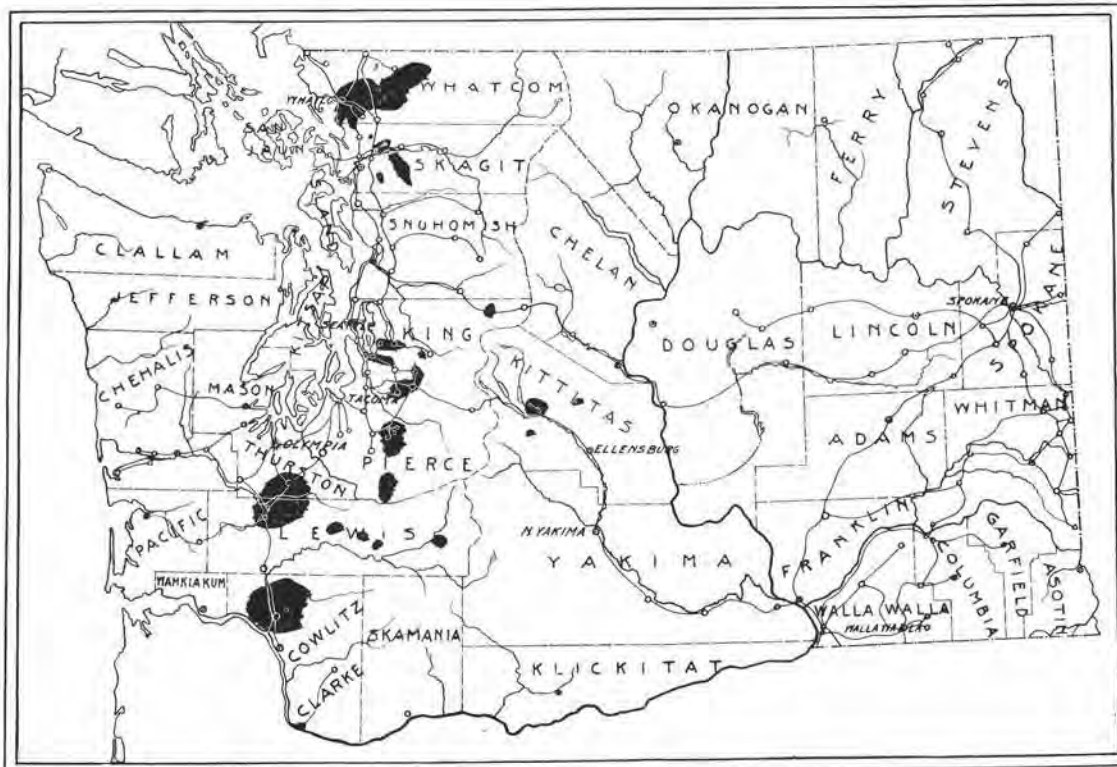
While analyses of the Washington cokes have not been made in connection with this report, the best data obtainable seems to indicate that they are high in ash and contain some phosphorus and sulphur. They are also soft cokes as compared with the best grades of coke for iron furnace work.

Washington has plenty of material suitable for fluxes and no fear need be felt in this particular. Labor is perhaps a little higher in Washington than it is in the East, but the difference would have very little effect on the price of iron. The whole Pacific Coast would furnish the market, as very little pig iron, if any, is being produced in any of the states west of the Rockies, except Washington, at the present time (March, 1902), and the steel and iron being used on the Coast is shipped from the East.

The results shown here are rather against the probability of Washington ever becoming a very large producer of pig iron from ores occurring within her own borders, at least, unless other deposits than those known at present are found. There is, however, one factor that has not been taken into consideration as yet, and that is the British ore occurring on Texada island and perhaps some of the other islands in the Straits of Georgia.

Number 7, in the table of analyses of Washington iron ores, shows the ore to be of very high grade, carrying 67.91 per cent. of iron, 2.96 per cent. of silica, 1.05 per cent. of calcium carbonate, and practically free from phosphorus and sulphur. This Texada ore is a heavy, black magnetite, and is said to occur in large quantities and is easy of access. The ore could be mined and loaded on boats or scows and transported to any place on the Sound at very small cost per ton.

If, on further investigation, it should be found that the Washington coke is suitable for use in the manufacture of iron, it is possible, perhaps, that by using the Texada ore alone, or by mixing it with the ores found in this state, that a considerable iron industry might be built up at some place on the Sound.



A MAP OF THE KNOWN COAL FIELDS OF WASHINGTON.

THE COAL DEPOSITS OF WASHINGTON.

BY HENRY LANDES.

INTRODUCTION.

The first authentic record we have of coal being found in Washington was in 1851, when some pieces of coal were picked up on the Stilaguamish river. Samples were sent to Washington, D. C., to be analyzed, and were found to be of good quality. Later investigations made by Rev. G. F. Whitworth showed however that the seams were too thin to be profitably worked.*

On Bellingham bay the first discovery of coal was made in the fall of 1852. Some work was done on the outcrop and about 150 tons were shipped, but by that time it was discovered that the coal was of poor quality and not in sufficient quantity to be of value, and it was therefore abandoned.

The next year, that is, in the fall of 1853, two men, Brown and Hewitt, discovered coal at Sehome. They were logging for the mill on Whatcom creek and found the coal where it had been uncovered by the uprooting of a large fir tree. They sent some of the coal to San Francisco for trial and a short time afterward received an offer of twenty thousand dollars for their claim, which they promptly accepted. For a number of years this was the only mine in the territory that was operated to any extent. It was finally abandoned a number of years ago.

In 1853 Dr. M. Bigelow found coal on Black river near Seattle. The vein was opened up and operated until the time of the Indian outbreak in 1855. Two of Bigelow's partners, Fanjoy and Eaton, were killed by the Indians and the mine was abandoned. Several attempts have since been made to re-open the mine but the coal contains too much dirt to make it profitable.

Early in the fifties coal was discovered on the Skookumchuck in the vicinity of the present town of Bucoda. The territorial

*Coal Mines of Western Washington, Rev. G. F. Whitworth. Resources of Oregon and Washington, Portland, Oregon, December, 1881.

penitentiary was located at this place and the convicts were employed for a number of years in the coal mine. When the penitentiary was removed to Walla Walla the mine was closed down.

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In 1863 two very important discoveries of coal were made. The first was at Issaquah or Gilman, and the other a month or two later on Coal creek near Lake Washington, about where the town of Newcastle now stands. A number of Seattle men, including Daniel Bagley, G. F. Whitworth, John Ross and other well known pioneers acquired an interest in the property and began active development. The coal was first carried to Lake Washington in wagons, transported across the lake by barges, and then carried to Seattle in wagons. In 1867 the Lake Washington Coal Company, consisting of the above named gentlemen and others, was incorporated for the purpose of carrying on more extensive developments. A new opening was made and the transportation facilities improved. The coal was carried down Black river to the Duwamish, thence down the Duwamish to Elliott bay. Barges were first employed and afterwards steamers.

In 1870 the property was sold to the Seattle Coal Company. The new company immediately began to construct a tramway to Lake Washington from the mine and another from Lake Washington to Lake Union over the portage. A little locomotive and train of cars brought the coal from the mine at Newcastle down to Lake Washington, where the whole train was loaded on a barge and carried over to Union bay were it disembarked onto the portage tramway. After passing over the portage the train was loaded on another barge on Lake Union and taken to the point where the Western mill now stands. From there the train proceeded up town to the coal bunkers, which were situated somewhere on Pike street.

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Early in the seventies Seattle was making determined efforts to secure railroad communication with the outside world. The Northern Pacific Railroad Company decided on Tacoma as its western terminus and showed a disposition to leave out Seattle altogether. The citizens of Seattle therefore organized the Seattle & Walla Walla Railroad and Transportation Company and began a line of their own. They constructed the road to Renton and Newcastle and from that time forward the old portage route was abandoned.

Coal was discovered near Renton in 1873 by Mr. E. M. Smithers. Together with T. B. Morris, C. B. Shattuck and others he organized the Renton Coal Company for the purpose of developing the property. The coal was run down on tram cars from the mine opening to the Duwamish river where it was loaded on barges and towed into Seattle.

The Talbot mine was opened near the Renton Coal Company's property in 1874. John Leary, John Collins and J. F. McNaught, who had control of the property, organized the Talbot Coal Company. After a few years of operation they found their vein badly faulted and finally abandoned it.

Somewhere about 1862 or 1863 a gentleman named Mr. Van Ogle discovered coal in the canyon of Carbon river. He found it in such large quantities and over such a wide extent of territory that he concluded that a single claim would be of no particular value to him, so he did not interest himself any further in the matter. During 1874 and 1875 a large number of coal claims were taken and considerable prospecting done. In 1876 the Northern Pacific Railway built a line to Wilkeson and afterward to Carbon Hill. The original Wilkeson mine was abandoned after about three years operation.

The Green river coal field was discovered at a later date. Since that time new discoveries have been made in a great many different places, so that the limits of the known coal bearing rocks are being gradually extended.

GEOLOGY OF THE COAL MEASURES.

For the most part the coal seams of Washington occur interbedded in a series of light-colored sandstones and shales, with sandstones as the predominating rocks. The latter are usually bluish or grayish in color, but often weather into light buff owing to the oxidation of the iron carbonate which they contain. These rocks are not confined to the districts where workable coal seams are known to occur, but outcrop at intervals over the principal part of western Washington. In some places the strata are found almost horizontal, but usually they are considerably folded and faulted and the upturned edges deeply eroded. Careful measurements of the series in the neighborhood of Puget sound, made by Mr. Bailey Willis, has shown a thickness of about ten thousand feet.

Carbonaceous matter is distributed in greater or less quantity throughout the rocks of the whole series. Small streaks of coal are found in most of the sandstones. The shales vary in color from light gray to black, according to the amount of carbonaceous matter present. All gradations are found between carbonaceous shale and pure coal. While the number of workable coal veins is small, being perhaps not more than ten or fifteen in any one district, the number of seams of more or less impure coal is very large, considerably over a hundred being known. All the veins thus far discovered which are clean enough and with the coal in sufficient quantity to be of commercial value are contained in the lower-most three thousand feet of the series. The upper two-thirds have thus far proven barren of workable seams, although rich in disseminated carbon. From the evidence of fossil leaves collected from various localities Professor F. H. Knowlton has determined these rocks to be of the Eocene age.

At the time these sediments were laid down the region between the present Cascade and Olympic mountains was a shallow sea or wide lagoon, more or less completely cut off from the ocean. That it was fresh or brackish water is shown by the character of the animal remains embedded in the sediments.* These are mostly unios or other fresh water forms.

During the whole of the long period in which these sediments were being deposited the region was undergoing a gradual but persistent sinking. The evidence of the coal seams in the lowest strata clearly shows that at that period the water at intervals was very shallow, and at the end of the period after sediments nearly two miles deep had been deposited the water still remained at about the same depth, showing that in the meantime the bottom of the sea had sunk two miles. These nicely adjusted forces of nature permitted the accumulation of a practically unbroken series of sediments throughout the whole period.

Subsidence did not take place at a uniform rate. There

*Invertebrate Fossils from Pacific Coast, C. A. White, Bulletin 51, United States Geological Survey, p. 56.

were periods during which the process of sedimentation shoaled the waters faster than the sea floor sank, and this continued until the water was shallow enough to support a swamp vegetation, which thereupon spread over the broad lagoons and flourished with great luxuriance. In regard to the climate, Professor F. H. Knowlton * says: "The lower beds, on account of the abundance of ferns, gigantic palms, figs, and a number of genera now found in the West Indies and tropical South America, may be supposed to have enjoyed a much warmer, possibly a subtropical temperature, while the presence of sumacs, chestnuts, birches and sycamores in the upper beds, would seem to indicate an approach to the conditions prevailing at the present day."

Alternating with the periods of coal formation, there were long lapses of time during which the water was too deep to admit of swamp growth. These were the times when subsidence proceeded at a more rapid rate than sedimentation, or at least kept pace with it. Sand and clay were then deposited. The final results of this intermittant, long continued subsidence was that we now have a large number of coal seams and layers of more or less carbonaceous matter interstratified with beds of sandstone and shale.

In order to maintain the water in a fresh or brackish condition either the outlet to the sea was very narrow or the climate must have been even more humid than it is at present. When we consider that notwithstanding the great volumes of fresh water being continually poured into Puget sound the water is not appreciably freshened it is difficult to account for the prevalence of fresh water forms in the Eocene sea except on the hypothesis that it was almost entirely cut off from communication with the open sea. The Olympic and Cascade mountains had not then risen to their present height but were probably rather in the form of low hills. The rocks of which they were formed were mostly of granitic type, as shown by the character of the sediments derived from them. The coal bearing rocks are known to occur along the western slope of the Cascade mountains from the northern border of the state southward to the Columbia river. It is probable that rocks of the same age form a rim around the foothills of the Olympics. Coal has been found in a number of places in

* Geological Atlas of the U. S., Tacoma Folio, U. S. Geol. Survey.

that part of the state, but owing to the very heavy forests and almost entire absence of roads very little is known about the region. Intermediate between the eastern and western parts of the field there was probably a nearer approach to marine conditions. Marine fossils found in Duwamish valley indicate that the border of estuarine conditions was somewhere between that locality and the coalfields to the eastward. The greater part of these fossils are identical with species found in the Tejon group of California, which is of Eocene age.*

VARIETIES AND USES OF THE COAL.

The coal is essentially a lignite in character. In certain limited localities, however, where great internal disturbance has taken place so that the coal has been crushed and rolled it has lost much of its volatile constituents and has become bituminous. The lignite is usually quite hard and breaks into more or less cubical forms. The bituminous coals are rather soft. They have been rolled out between their walls and thoroughly crushed, so that a considerable percentage of the volatile constituents have escaped and the coal is consequently richer in fixed carbon. The semi-bituminous or steaming coal lies midway between these two. Frequently the change from lignite to bituminous and back again occurs within the same vein.

The value of the coal depends upon the varying percentages of moisture, ash, sulphur, volatile hydro-carbons, and fixed carbon. In regard to the first three of these the smaller the percentage the greater will be the value of the coal. The ash is derived from two sources: 1st, the natural ash present in the plant from which the coal is derived; 2d, the dirt carried into the original coal swamp by streams and deposited with the coal. This latter source is usually by far the most important one. In a large number of coal seams it is the high percentage of ash rather than any other drawback which prevents the coal from being placed on the market. A number of representative analyses of coal from the principal mines show a range in the percentage of ash from 5.76 to 12.55. The samples from which these analyses were made were presumably taken so as to represent a fair average of the commercial article as it was placed on the market.

* Correlation Papers, Eocene, W. B. Clark, Bulletin 83, U. S. Geol. Survey, p. 108.

A high percentage of moisture detracts from the heating qualities of the coal because all the moisture has to be volatilized before any of the heat energy is available for any other purpose. The lignites of course contain more moisture than the bituminous coal and consequently have not such high heating qualities.

A certain percentage of volatile hydro-carbons is essential to coal. For steam generating purposes the semi-bituminous has been found to be the best. It has a representative analysis as follows: moisture, less than 5 per cent.; ash, 5 to 10 per cent.; volatile hydro-carbons, 30 to 40 per cent.; fixed carbon 40 to 50 per cent.

The Puget sound coals are suited to a variety of purposes. The output of some of the mines is used almost exclusively for steam generating purposes, as those of Franklin. Probably more coal is used for this purpose than for any other. A large quantity is used for domestic purposes. Coke making is becoming quite a large industry and several of the mines use a large part of their output in their coke ovens. The coke finds a ready sale, being more suitable for certain purposes. The only coal now used for gas making purposes is that found at Burnett. It is used exclusively in the Sound cities and in Oregon and California. It gives off a high percentage of illuminating gas and the residue cokes readily. A small vein of coal has been found at Fairfax suitable for blacksmithing and this finds a market at a high price.

Eastern Washington is largely supplied by the Roslyn mines which are the largest in the state. A considerable quantity of this coal finds its way to Seattle, where the company has recently erected large coal bunkers to take care of their export trade. A large part of the coal of western Washington is shipped to San Francisco and other coast ports. A considerable quantity is shipped to Alaska. The rise of the petroleum industry in California has caused a considerable falling off of the coal trade with the latter section. In the coastwise trade the coal of Washington competes with that of British Columbia and Oregon.

WHATCOM COUNTY.

In the western part of Whatcom county, extending from the foot of Mt. Baker to the coast, there is an area of Eocene coal measures embracing over 250 square miles. These coal measures are composed mainly of massive sandstones and conglomerates, and shales, and are exclusively of lake origin. They have a total thickness of many thousands of feet. Within them very much vegetal matter in the form of lignite or coal is to be found, often in irregular masses or pockets, but now and then in a well-defined seam. Occasionally these seams assume dimensions sufficiently large to afford workable coal, and they are then of economic importance. In all cases, as far as known, the beds of coal are not immediately underlaid by clay, but by conglomerate or sandstone, showing that the coal was not formed by the plants which grew upon that particular spot, but rather that it was formed from drift wood. As a result no individual seam of coal can be expected to extend throughout the coal basin, or even over a large part of it, but is more local in its extent. It is also true that a coal seam will show considerable variability in thickness when followed in different directions.

Since their deposition the coal measures have been greatly folded and the strata are now inclined at high angles. Erosion has removed large portions of them, as may be seen in the wide valleys of the Nooksack and its tributaries, in the basin of Lake Whatcom, and elsewhere. In the eastern and central parts of the Whatcom coal field the strata outcrop everywhere and the coal beds may be easily found, but in the western part of the coal field the rocks pass under a heavy mantle of glacial drift and may only be studied or prospected by diamond drilling.

In the Whatcom coal field veins of workable coal have been found at a number of places. In some instances extensive mines have been opened and large quantities of coal produced. In a general way the coal may be said to improve in quality from west to east, as one passes from the region of least folded rocks to those that have suffered the greatest deformation. The coal vein now being developed on Cornell creek, within six miles of Mt. Baker, is said to be of a better quality than any other so far found in this field.

The Bellingham bay coal vein is the uppermost one in the Whatcom coal field. It is 14 feet thick, a lignite in quality, and was extensively worked 20 years ago. Its outcrop is north through the middle of the city of Whatcom and thence northwesterly, dipping west and southwest from 8 to 10 degrees.

Blue Canyon District.

The Blue Canyon mine is located on the southeastern shore of Lake Whatcom, on the railway of the Bellingham Bay Improvement Company. The vein of coal that is being worked varies much in thickness, but averages about 7 feet. It lies at the very base of the coal measures, being separated from the mica schist lying below by a layer of conglomerate which varies from six inches to three feet in thickness. Where the conglomerate is thinnest the coal vein is greatly broken and shattered, and is occasionally faulted. Lying as it does between the massive sandstones above and the metamorphic rocks below the vein has suffered greatly in the deformation of the coal measures. The vein pitches to the northwestward at an angle of 50 or 60 degrees.

The Blue Canyon mine has been in operation for a number of years, but has done little more than supply the demand of the cities and towns of Bellingham bay and thereabouts. The coal is very desirable for steaming and for domestic purposes. In 1901 the output of the mine was 48,200 tons.

SKAGIT COUNTY.

In the western half of Skagit county coal measures of Eocene age outcrop at a number of places. Surrounding these outcrops, as a rule, there are small coal basins, which seemingly have never been connected but have always been separated one from another. In the northwestern part of the county the large coal field of Whatcom county extends into Skagit for a little way. A mile west of Thornwood, on Samish river, there is an outcrop of coal where a little development work has been done. Immediately east of Montborne there is a small area of coal measures with a few coal outcrops. Near Cokedale and Hamilton there is in each case a coal measure area in which well known veins of coal occur.

The coal-bearing rocks above mentioned are composed essentially of shale, sandstone and conglomerate, with very much irregularly embedded vegetal matter in the form of lignite or coal. These deposits have been made in lakes which were enclosed in basins of metamorphic rocks, mainly schists and slates. After the lake sediments accumulated to a great thickness they were folded to such an extent that the strata are now often inclined at high angles. Since the disappearance of the lakes the lacustrine sediments have been largely removed by erosion, and it is possible that the removal has been so great in the cases of the smaller lake deposits that some of these have not yet been discovered.

Cokedale District.

At the town of Cokedale a coal mine has been in operation for a number of years. The mine is located at the extreme northern limit of the coal basin, the lowest vein of coal being but a few feet from the schist which lies below. The coal measures of Cokedale outcrop along the northern boundaries of the district, but for the most part they are covered by the alluvial deposits of the Skagit river. The district is not believed to be a large one, extending from Cokedale southward to the Skagit, and in an east and west direction from near Lyman to a point a little way beyond Sedro-Woolley.

At the Cokedale mine three veins of coal are found, viz.: the north or Klondike vein, the middle vein, and the south vein. The north vein is the lowest one in the series and has a thickness varying from 10 to 25 feet; the middle vein lies 140 feet above the north vein, stratigraphically, and has a thickness of from 4 to 8 feet, with an average of 6 feet; the south vein, lying 40 feet above the middle vein, has a thickness varying from 6 inches to 2½ feet. The north and middle veins only are worked at the present time.

The Cokedale coal veins at their outcrops stand about vertical, but in the lower mine workings they dip slightly to the southward. In the deformation of the coal measures the coal was so greatly broken that in mining it it is obtained only in small pieces, and never in large lumps. It is a good coking coal, and a large part of it is made into coke. The coal is all passed through washers after leaving the mine; the coarser part is then used for steaming and domestic purposes, while the finer part is taken directly to the coke ovens near by. The ovens are of the bee hive pattern, each having a capacity of five tons. Forty ovens are in place, ten of which were operated continuously during 1901. In 1901 the output of the Cokedale mine consisted of 12,643 tons of coal and 5,806 tons of coke.

Hamilton District.

A few miles east of the Cokedale district, and near the town of Hamilton, is a region of coal-bearing rocks known as the

Hamilton district. This district lies chiefly between Cumberland and Day creeks, and extends from the Skagit river to the neighborhood of Deer creek. The rock outcrops of the Cokedale and Hamilton districts, are separated by the broad alluvial plain of the Skagit, and it is not known at the present time whether the coal-bearing rocks extend from one district to the other.

At several places in the Hamilton district coal veins of commercial importance are known to outcrop. Upon some of these veins considerable development work has been done, and in times past some coal has been mined and sold. The coal is of good quality, and of a variety that may be made into coke. As a rule the coal veins lie in such a position that they may be worked very readily.

On the property of the Skagit Cumberland Coal Company and on the lands of Mr. J. J. Conner, near the mouth of Cumberland creek, there are a number of outcropping coal veins. The first of these is located on the bank of Cumberland creek, not far from the contact of the coal measures with the underlying mica schist. This vein of coal has a strike of south 43 degrees east, and a southwest pitch of 55 degrees. It lies between sandstone walls, and has a thickness of about seven feet of clean coal. About a hundred feet stratigraphically above the vein just mentioned, is a second coal seam having approximately the same dip and strike, with a thickness of over five feet. Above the outcrop of the number two vein, at varying heights on the mountain side, there are outcrops of several other veins of coal with thicknesses ranging from a few inches to four feet.

Toward the southern part of the Hamilton district, in the region about Day lake, coal outcrops at a number of places. In a few instances some development work has been done. In sections 13 and 24 T. 34 N., R. 6 E., the coal veins have a thickness varying from 8 to 12 feet.

KING COUNTY.

Newcastle-Issaquah District.

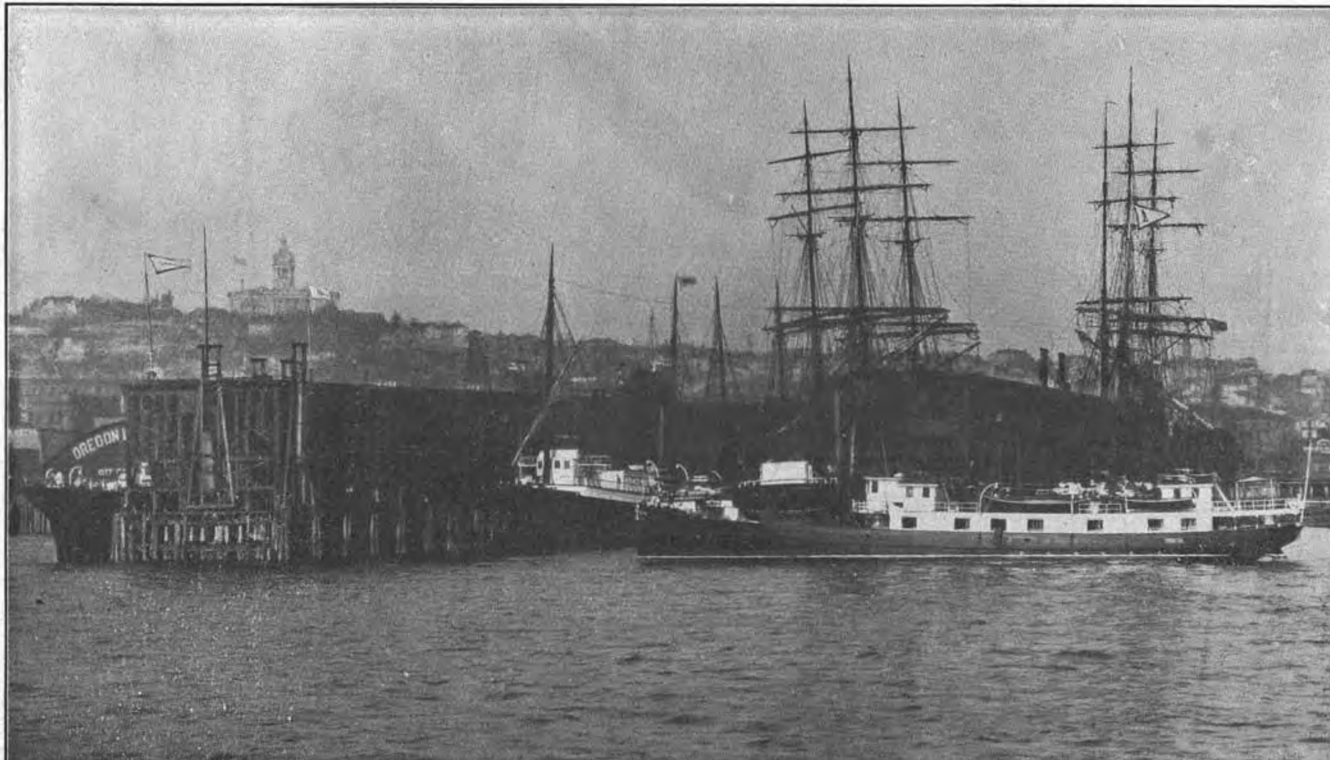
The Newcastle-Issaquah district probably constitutes one continuous coal field. The Issaquah mine, formerly known as the Gilman mine, is located at the northern base of Squak mountain, two or three miles from the southern end of Lake Sammamish, and about fifteen miles east of the city of Seattle.

Squak mountain is a mass of volcanic rock of the variety known technically as pyroxene andesite. The coal measures overlie the lava and dip to the northward at an angle of from twenty to forty degrees. The strike of the strata is nearly due east and west. Only one fault of any consequence has been encountered in the Issaquah mine, and that has not seriously interfered with the process of mining. In this mine the workings have been pushed westward through Squak mountain, under the valley of Tibbetts creek and into the Newcastle hills.

A branch line of the Northern Pacific Railway reaches Issaquah by way of the northern end of Lake Washington, and the coal is shipped by that route. The mine was opened by the Issaquah Coal and Iron Company in 1887. Their holdings embrace a tract of land five miles long by one and a quarter miles wide. Up to the present time they have worked out about three hundred and twenty acres of coal, and have produced altogether about 1,500,000 tons of coal. The output for 1901 was 121,829 tons. It is expected that the output for 1902 will be considerably larger. There are seven known veins of coal on the property having a thickness respectively of four, five, six, eight, nine, twelve, and fourteen feet.

According to the statement of C. F. Owen, State Inspector of Coal Mines, the coal generates very little gas and can be worked in safety with open lights. It is used very largely for steaming and domestic purposes.

On the Newcastle side of the mountain the principal openings have been made along Coal creek, a small stream flowing northwestward into Lake Washington. Most of the coal has come from the vicinity of the town of Newcastle, where it has been mined extensively for the last forty years. These mines are among the oldest in the Puget sound region and have up to the present time produced about five millions of tons. The coal is taken out by way of the Columbia & Puget Sound Railway, which reaches Seattle by way of Renton and the Duwamish valley. Both mines and railroad belong to the Pacific Coast Company, formerly the Oregon Improvement Company. The present Newcastle mine was opened in 1895, and is now practically worked out. It has produced altogether nearly 600,000 tons of coal. There are five veins, having a width of three feet four inches, four feet, four feet six inches, six feet and eight feet, re-



COAL BUNKERS, SEATTLE.

spectively, and there are about ten miles of gangways and slopes. The breast and pillar system has been employed in the mine. Most of the coal is used for domestic purposes and for generating steam.

Since the Newcastle mine has been virtually abandoned active operations have been transferred to the new Coal Creek mine about a mile and a half farther up the stream. This mine was opened in 1898 and up to January 1, 1902 had produced about 300,000 tons. The daily output is now on an average 750 tons. For the year 1901 the total output was 130,957 tons. Four veins are being worked, two of them three feet eight inches in width, one four feet two inches, and one five feet. In the present workings the veins strike approximately east and west and dip north thirty-eight degrees. A double track working tunnel, seven by fourteen feet in diameter, has been driven a distance of 5,400 feet. There are altogether about three miles of gangways. In the main tunnel electric motors are employed for hauling, and electric lights are used. The breast and pillar system is the one adopted. A 375 h. p. plant generates electricity for hauling, lighting, ventilating, running the air compressor, running the washing machines, etc. The company uses a rotary washer of their own manufacture.

Renton-Cedar River District.

The depression occupied by Lake Washington is continued southward first as Black river valley, and then as White river valley. Less than a mile from where Black river leaves Lake Washington Cedar river enters the former from the eastward, flowing through a narrow, steep-sided valley for a number of miles and entering the broader valley at the town of Renton. Between the valleys of Cedar river and White river there is a plateau which from the surface indications seems to be composed entirely of glacial drift. It has an average elevation of about four hundred feet above the level of the bordering valleys. Along the steep sided northern and western edges of this plateau, especially near the town of Renton, the coal measures outcrop from beneath the covering of glacial drift. Seven or eight miles farther up the valley of Cedar river the coal-bearing rocks are again exposed where the Cedar mountain mine has been opened. On the northern side of Black river between

Renton and the Duwamish river the coal measures appear in a nearly horizontal position.

The first mine to be operated on an extensive scale in the vicinity of Renton was the old Renton mine, which was opened by a number of Seattle pioneers early in the seventies. This mine has long since been worked out, as has also the Talbot mine, opened a year or two later. In 1895 the Renton Co-operative Coal Company began operations on a tract of unoccupied ground between the two old mines. They afterwards sold out their property to the Seattle Electric Company. The new owners are now working on two veins, No. 2 and No. 3, each of which is about six feet thick, and they are driving a tunnel to open a third vein. There are about 9,000 feet of underground main tracks. The pillar and stall method of mining is employed. At present the daily output averages about 400 tons, and the total output for 1901 was 72,865 tons. The coal is used mostly for steaming and domestic purposes. It is washed by means of Howe washers. All the hoisting, pumping and lighting is done by means of a 150 h. p. electric plant.

Eight or nine miles up Cedar river from Renton is the Cedar mountain mine. The first openings in this vicinity were made about twenty years ago and for a long time the mine was a great producer, but the principal vein was lost and has only recently been rediscovered. The Cedar Mountain Coal Company obtained control of the property in 1898 and since that time has been working on an eight-foot vein. The total output for 1901 was 13,500 tons.

Green River District.

A thick section of the coal measures is exposed in the canyon of Green river, T. 21 N., R. 6 and 7 E. There are altogether forty beds of carbonaceous matter included in this section, but only four of them are productive coal beds. These outcrops were discovered about 1880, and two or three years later the Franklin and Black Diamond collieries were opened. The only vein that is now worked very extensively is the McKay vein, otherwise known as the Light Ash or White Ash vein. The strata in this district are thrown into long open folds, and the whole series inclines to the southwest. Several faults have been encountered in the course of mining and in each case the hanging wall has slid downwards. Three of these normal faults occur in the Black Diamond mine. In the Franklin mine there are a number of small faults. In the eastern part of the field where the greatest disturbance has taken place in the rocks the coal has become highly bituminous, while in the northwestern section where the rocks remain more nearly in their original position, the coal remains a lignite.

The Gem mine at Franklin, belonging to the Pacific Coast Company, was opened in 1899 and has, up to date, produced 75,000 tons of coal. The total output for the year 1901 was 36,460 tons. It has now a daily output of 180 tons. The vein which the company is now working has a thickness of two feet seven inches of good, clean coal. In the present workings the vein strikes nearly due north and south and dips thirty-five degrees to the west. It is said that the vein can be traced for three miles on the surface of the ground. An estimate of the coal still to be mined places the amount at about 2,500,000 tons. The total length of underground workings is not far from 3,000 feet. A 75 h. p. steam engine is used for hoisting and ventilating. The chute and pillar system of mining is employed altogether.

The Franklin No. 1 and No. 2 was operated for a number of years, but was flooded and abandoned some time ago. It is now being reopened and will be operated again on an extensive scale in the near future. Since starting again it shipped, prior to January 1, 1902, 4,494 tons, and has now a daily output of 50 tons. Two veins are being worked, one four feet and the other nine feet in thickness. They are worked on the chute and pillar system. A 500 h. p. steam plant is employed for hoisting, ventilating, pumping, and operating the coal washing machinery. It also runs the air compressor, which is used for running the drills and other mining machines. The coal washers are of the rotary pattern and are the company's own manufacture. The coal is nearly all used on locomotives and steamers. The mine is the property of the Pacific Coast Company.

Franklin No. 7, opened in 1895, has produced about 700,000 tons of coal up to the present time and has now a daily output of 300 tons. The the total output for the year 1901 was 88,217 tons. One vein is being worked which has a thickness of four feet six inches. There is a 500 h. p. plant for hoisting, pumping, ventilating and lighting. The slope has now been driven in a distance of 3000 feet and there are altogether about five miles of gangway. Electricity is used for lighting wherever possible. The breast and pillar system of mining is employed. The coal is used largely for steam generating purposes in steamers and manufacturing plants.

The Lawson mine near Black Diamond, which is also the property of the Pacific Coast Company, was opened in 1895 and has had a total output up to the present time of 260,000 tons. The company is working on vein No. 1, better known as the McKay vein, which is four feet and four inches in thickness, all of clean coal. There is now being mined on an average 400 tons per day. The coal is used very largely on steamers and in factories; also for domestic purposes. There are now three miles of underground gangways, and a slope fourteen hundred feet long. All the mining is done on the chute and pillar system. Steam power of 375 h. p. is used for operating the hoisting, ventilating, pumping and other mine machinery. Electricity is used for lighting wherever possible. It is estimated that the mine still contains about 5,000,000 tons of coal. For the year 1901 the output was 97,329 tons.

The Black Diamond mine was first opened about nineteen years ago. The property is now being operated from two openings on the McKay vein, known as Mine 14 and Morgan's Slope. The coal is good, clean steaming coal and requires very little picking or washing. It produced in 1901, 227,000 tons.

The Seattle & San Francisco Railway Company's mine at Ravensdale, formerly known as Leary, was opened two or three years ago when the district was given transportation facilities by the construction of the Palmer cut-off of the Northern Pacific railway. It is situated seven or eight miles west of Palmer. Four veins are now being worked. Prior to 1901 the mine shipped 48,000 tons and for 1901 the total output was 63,578 tons. The company has lately constructed large coal bunkers at West Seattle.

PIERCE COUNTY.

Wilkeson-Carbonado District.

This field lies about midway between the city of Tacoma and Mount Rainier. All of the producing mines are in the extreme northern part of the field and not far from the main line of the Northern Pacific Railway. Carbon river, which derives its name from the numerous outcroppings of coal along its course, flows for about eight miles through the district. Just above the town of Carbonado the river flows through a steep sided canyon in volcanic rock, but at the town and for a mile or two down the river the coal series is exposed. Other sections occur along Gale creek and South Prairie creeks, tributaries of Carbon river. The hills are covered with glacial drift to a depth of from fifty to three hundred feet. In addition to this the whole region is very heavily timbered, so that surface prospecting can be carried on only along the stream channels. Measurements made by Mr. Bailey Willis,* of the sections exposed along the streams and in the mine workings showed a thickness of 8,000 feet of barren measures lying above the productive coal beds.

Coal was first discovered on Carbon river forty years ago, and the first location was made by Flett Brothers and their brother-in-law Gale, about ten or twelve years later, that is, in 1874. They made the first opening on Gale creek about half a mile above the present town of Wilkeson. A wagon road was constructed from South Prairie to the mine and a number of tons of coal hauled to Tacoma.

The Burnett mine is the most northerly one now operated in this field. It was opened by Mr. C. H. Burnett in December, 1881, and has now passed into the hands of the South Prairie Coal Company. A short branch line connects the mine with the Northern Pacific Railway at Cascade Junction. Four veins have been worked to a greater or less extent, but there are only two at present from which coal is being taken. They are both about three feet in thickness. The total output since the mine was first opened is estimated at 930,000 tons. At the present time about 300 tons per day are being shipped. The total length of underground workings is at least two miles. The coal is used for domestic purposes, for steaming, and for the manufacture of gas. The coal is washed by means of Howe washers. A 300 h. p. steam power plant is employed for hoisting, pumping, etc. Seventy-seven thousand two hundred and fifty-five tons were produced in 1901.

The Wilkson mine, operated by the Wilkeson Coal and Coke Company, is on a branch line of the Northern Pacific railway about thirty-one miles from Tacoma and two miles south of Burnett. It was opened in 1879 and at the present time there are

* Willis: Coal Fields of Puget Sound, 18th Ann. Rep. U. S. Geol. Survey.

about six miles of water level gangways. The estimated total output since the mine was started is 1,000,000 tons. The daily output now is 500 tons. Six veins are being worked, having an average thickness of six feet each. The chute and pillar system of mining is employed. Forrester patent washers are used. The power consists of two steam stationary engines of 130 h. p. and two locomotives. Mules are employed underground. The company has a large coking plant in operation and most of the output of the mine is converted into coke. There are fifty ovens built on the bee hive pattern, twelve feet in diameter, which turn out about seventy tons of coke per day. Fifty more ovens are being erected which will give a total daily output of 100 tons. In the year 1900, 47,615 tons of coal were converted into 29,309 tons of coke. For the year 1901 the total output was 125,028 tons of coal. The veins which are now being worked outcrop on the surface along Gale creek in the western part of section 27. The strata here are bent into a broad, low arch with a number of smaller folds. Operations have been conducted on each side of the main arch and a number of faults have been encountered. The present company operating the mine owns the land on the western side of the arch. On the eastern side where the veins dip to the eastward the land belongs to the Northern Pacific Railway Company, but is worked by the Wilkeson Coal and Coke Company on a royalty in connection with their own property. Only one quarter of the available coal above water-level has been worked out and there are several millions of tons below water-level that can be mined at a profit.

The Carbonado mines are opened about two miles south of Wilkeson on Carbon river, which here flows through a canyon about three hundred and fifty feet deep. The railroad was extended from Wilkeson to Carbonado about the year 1880 and shipments of coal at once began. Four veins are now being worked which have a thickness of four feet six inches, five to six feet six inches, five feet, and seven feet four inches respectively. The total output has been over four millions of tons. The output for 1901 was 323,395 tons. A battery of 75 coke ovens is being installed.

The Gale Creek Company and the Willis Coal Company are opening up new mines in the district. The Gale Creek Company is working five veins from three to seven feet thick, and has taken out about one hundred thousand tons of first-class steaming and gas coal. Their output for 1901 was 18,900 tons. The Willis company has six veins, from three to six feet thick, and has taken out several thousand tons.

The Western America Company, operating the Fairfax coal mine, has built a railroad seven and a half miles long to connect with the Northern Pacific at Carbonado. They began operations in January, 1900, and are now producing about two hundred tons per day. For the year 1901 their output was 30,513 tons. Three veins are being worked: No. 2, six feet thick, No. 3, six feet eight inches thick, and Blacksmith vein, two feet six inches thick. A water-power plant of 125 h. p. is used to generate electricity for lighting, hauling, etc. There are now about 3,000 feet of gangways with smaller workings to match. The diamond system of mining is principally employed. The company has gone into the coking industry on an extensive scale. They have now in operation sixty bee-hive ovens thirteen feet in diameter and seven feet in height. Besides being made into coke, the coal is very largely used for blacksmithing and for steam making.

The Montezuma mine has been opened in section 2, T. 17 N., R. 6 E. Work was begun in February, 1901, and up to the present time about 800 feet of entries and airways have been driven. No attempt has yet been made to stope out the coal and no shipments have been made, but in the course of driving the entries from twenty-five to thirty tons of coal per day are taken out. The long wall system of mining will be employed. The company has ordered one hundred bee-hive coke ovens and as soon as these arrive most of the output of the mine will be converted into coke. A 400 h. p. turbine wheel has been installed, and all the hoisting, hauling, etc., will be done by water power. Three veins are being worked, having a thickness of three feet six inches, seven feet and nine feet, respectively. Two rock tunnels are being driven which will crosscut two or three more veins, one five feet, one nine feet and another of unknown thickness.

KITTITAS COUNTY.

Roslyn-Clealum District.

The Roslyn and Clealum coal field, situated in the northwestern portion of Kittitas county, on the line of the Northern

Pacific Railway, is separated from the coal fields of western Washington by the main range of the Cascade mountains.

The coal occurs in a series of light colored sandstones to which the name "Roslyn sandstone" has been given. This formation is underlaid by a series of sheets of basaltic lava, which in turn are underlaid by other sandstones. The thickness of the Roslyn sandstone has been estimated as at least 3,500 feet.* Fossil plants from the Roslyn coal mine and from other coal seams about Clealum have been identified by Professor F. H. Knowlton as being of Eocene age. This makes the Roslyn coal roughly contemporaneous in origin with the coals of western Washington.

The Roslyn coal mine, owned and operated by the Northwestern Improvement Company, is the largest in the state. A branch road three or four miles long runs from the main line of the Northern Pacific Railway at Clealum to this mine. The mine was first opened in 1885 by the Northern Pacific Coal Company, which was afterwards reorganized as the Northwestern Improvement Company. The coal vein is four feet eight inches in thickness and dips at Roslyn from thirteen to twenty-six degrees to the southwest. It is bituminous and an excellent steaming coal. The output for 1901 was 1,005,027 tons, having a value at the mine of over $1,500,000. Up to November 1, 1901, the total output since the opening of the mine was 5,826,727 tons, taken from an area of about one thousand acres. A conservative estimate of the Northwestern Improvement Company's holding of ten thousand acres places the total amount of coal still remaining at forty-seven millions of tons.† The Roslyn vein is supposed to extend under the entire Clealum valley at a depth of eleven hundred to fifteen hundred feet. It occupies a shallow syncline with an east and west axis.

The Clealum mine, operated by the same company as the Roslyn mine, was opened in 1894. The vein upon which they are now working occurs higher in the series than the Roslyn vein. It is from four and one half feet to five and one half feet thick and dips southward at an angle of about fourteen degrees.

The Ellensburg Coal Mining Company has operated a mine

* Geology of the Cascade Mountins in Northern Washington, I. C. Russell, 20th Ann. Rep. U. S. Geol. Survey.

† 9th Biennial Report, State Inspector of Coal Mines, C. F. Owen, 1901.

NO. 4 OPENING AND ELECTRIC LIGHTING PLANT AT ROSLYN COAL MINES.

in a small way situated two miles north of Clealum. The vein is four feet thick.

Other coal outcrops occur on the Teanaway river north of Clealum, on Frost creek, on First creek, Naneum creek and on Williams creek.* Not much development work has been done on any of these properties, so it is not known at present whether or not the coal occurs in commercial quantities.

THURSTON COUNTY.

Bucoda-Tenino District.

The Bucoda-Tenino district lies in the southern portion of Thurston county. Its boundaries are not definitely fixed in any direction. A large part of its surface area is composed of flat river bottom and barren gravel plains, and it is only where the coal-bearing formation appears at the surface along the hillsides and on higher ground that it is possible to discover any outcroppings of coal.

Coal was first discovered in the valley of the Skookumchuck in 1855. It was mined in the vicinity of Bucoda in early territorial days, the convicts of the penitentiary being employed for that purpose. The early mines are now closed down and it is difficult to get definite information regarding them.

The Chehalis and Skookumchuck rivers flow through wide, level valleys. Hills of sedimentary rocks belonging to the coal-bearing series border the valleys and rise to heights of several hundred feet. During late glacial time the melting of the great ice mass which occupied the basin of Puget sound caused a tremendous flood of water to sweep southward over this region. This great river was heavily loaded with sediments of all degrees of coarseness, which it dropped by the wayside as it passed along. In the northern part of the field in the vicinity of Tenino the gravel is quite coarse, and water-worn boulders are scattered everywhere. Traveling southward into Lewis county the material gets finer and finer until in the vicinity of Chehalis it is a fine sandy loam with no gravel. South of Chehalis there are no signs of glacial action whatever.

The Great Western Coal Company, of Spokane, have a mine about four miles southwest of Tenino in section 35, T. 16 N., R.

*Geology of the Cascade Mountains in Northern Washington, I. C. Russell, 20th Ann. Rep. U. S. Geol. Survey.

2 W. Considerable prospecting work has been done with a diamond drill. A tunnel three hundred feet long has been driven and crosscuts made. The vein upon which they are working is about three feet six inches in thickness. At the present time the coal is hauled to the railroad in wagons, and about two car loads a week are shipped. The coal is said to be of good quality. It is a lignite like all the rest of the coal in this field.

The Seatco coal mine was opened in 1880 near the town of Seatco, the name of which was afterwards changed to Bucoda. It was operated with convict labor taken from the territorial penitentiary, which was at that time located at Seatco. Public sentiment was hostile to the enterprise, however, so that the convict system was soon discontinued and the mine closed down. Of the original penitentiary company, composed of Messrs. Billings, Smith and Shead, Mr. Billings is the only surviving member. They operated on an eight foot vein of coal and took out altogether about ten thousand tons.

LEWIS COUNTY.

Chehalis-Centralia District.

The two towns of Chehalis and Centralia lie about four miles apart, on a wide river plain. Along the sides of the valley coal outcroppings have been found and a number of openings have been made, but none of them have developed into extensive mines. A little coal is being taken out to supply the local demand. Nearly all of it is used for domestic purposes. The electric power plant of Chehalis uses it for making steam.

In the hill back of the town of Chehalis a number of prospects have been opened up in the past. Several years ago prospects were opened up on the Rosenthal property, but they have since been closed. At the present time there is one small mine working about a mile from town in Sec. 29, T. 14 N., R. 2 W. It is operated by Miller Brothers. They have driven a tunnel about one hundred and twenty feet on a vein which measures four feet three inches in thickness and dips about forty-five degrees. They began work in October, 1901, and at the end of the year had taken out about four hundred and thirty tons. The coal is all sold in the town of Chehalis. It is a lignite of fair quality, but leaves a large amount of ash.

There is only one coal mine operating at present in the vicinity of Centralia. It is the Salzer Valley Coal Mine, situated in Sec. 22, T. 14 N., R. 2 W., about four miles east of Centralia. This mine has been operated in a small way by Mr. Marion Howell for the last four years. For the last three months of the year 1901 the output was 267 tons. The vein is five feet six inches in width and lies nearly horizontal. A tunnel one hundred and fifty feet long has been driven. The coal is hauled in wagons to Centralia and Chehalis and sold for domestic purposes.

A new mine is being opened up by the Sterling Company in the Hanaford valley in T. 14 N., R. 1 W., about eight miles east of Centralia. A railroad will be built from the mine to the Northern Pacific Railway, a distance of a little more than nine miles. The junction will be about a mile and a half north of Centralia. The company owns nine hundred acres of coal lands. Three veins will be worked, the first seven feet four inches thick, the second fourteen feet thick, and the third five feet eight inches thick. The coal is a lignite and is said to have a low percentage of ash. At the point where the veins are being opened up they dip about eleven degrees from the horizontal.

The old Florence or Ellsbury mine is now closed down. It was worked for a number of years and had a total output of about ten or fifteen thousand tons. It was finally abandoned seven or eight years ago.

Some coal was taken out of another mine on Sec. 3, T. 14 N., R. 2 W., but it was also abandoned about four years ago.

To the eastward coal outcrops have been found at intervals nearly all the way to the summit of the Cascades. At several different places extensive development work has been done. In the western part of the field the coal is lignite, but as it approaches the Cascades it is said to develop into bituminous coal and finally into anthracite.

COWLITZ COUNTY.

Kelso-Castle Rock District.

The Kelso-Castle Rock coal field embraces nearly all of the northwestern part of Cowlitz county. The Cowlitz river runs north and south through the center of it. The country is, for the most part, very heavily timbered and the hills are worn into low, rounded forms so that the solid rock does not show in many places. The soft coal bearing rocks have been decomposed to considerable depths and a residual soil many feet in thickness has been formed. For this reason the boundaries of these rocks are not definitely known. It is probable that as the district becomes better known the boundaries of the area of productive coal measures will be greatly extended.

Throughout this part of its course the Cowlitz river flows through a flat alluvial valley a mile or two in width, bordered by low hills which gradually increase in height as they recede from the river. The tide flows up the river several miles above Kelso. At Rocky Point and at Castle Rock bold bluffs of hard basaltic lava extend out into the valley. In the vicinity of Kelso and higher up the river there are the remants of a rocky bench or terrace about fifty feet in height above the level floor of the valley.

The coal bearing rocks are sandstones and shales probably of Eocene age. They have been upturned from their original horizontal position only to a slight degree. Along the Cowlitz river the rocks are thrown into gentle folds. A large number of coal seams have been found at different places varying from a few inches to six or eight feet in thickness.

The Anchor mine was opened in 1890 by the Anchor Coal and Development Company, of San Francisco. It is located in Sec. 13, T. 8 N., R. 2 W., about three miles northeast of Kelso. Two veins were worked, one about four feet and the other five feet in thickness. A narrow gauge railroad three-quarters of a mile long ran from the mine to the Cowlitz river where the coal was loaded on barges and shipped to Portland and other places. Although a large amount of money was spent, the mine did not turn out to be a success. It was finally abandoned about 1898.

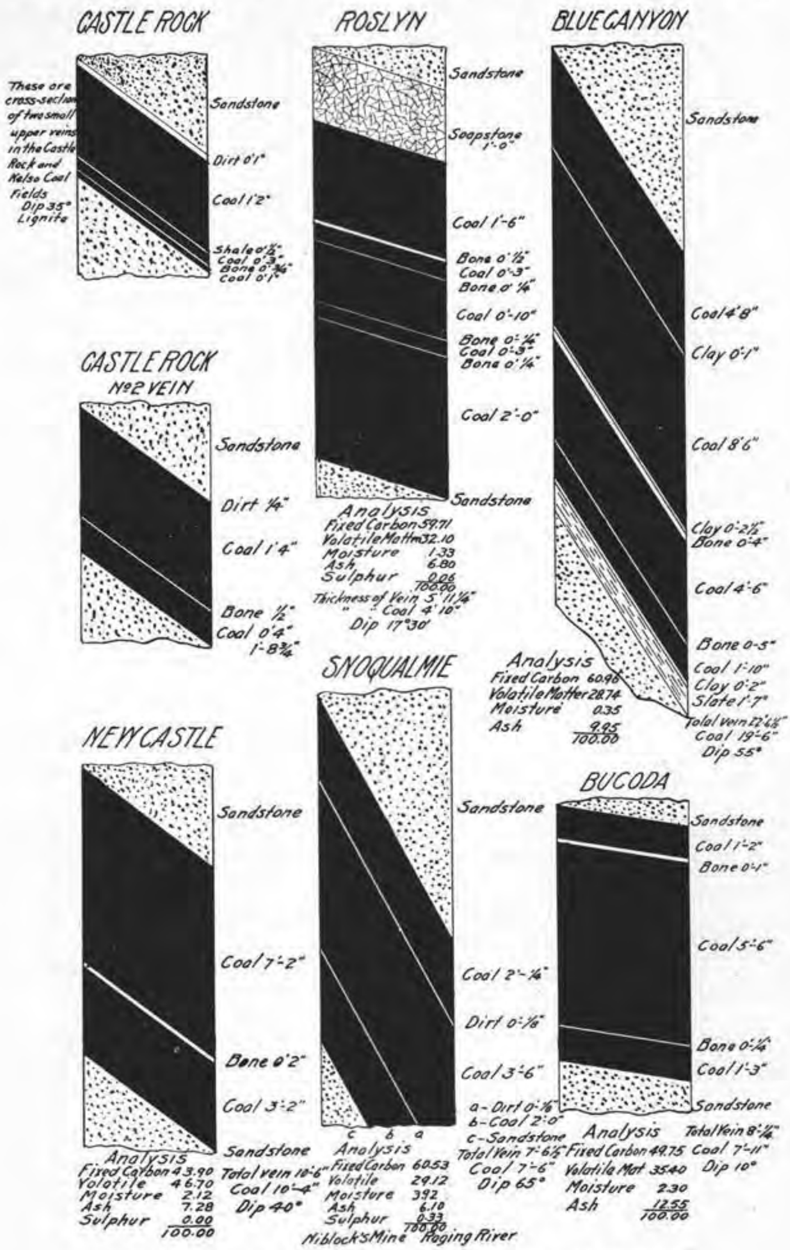
The Coal Creek Development Company, of The Dalles, Oregon, is opening up a coal prospect on Coal creek, about eight miles west of Kelso. A standard gauge railroad is being built from the mine to tide water, a distance of four miles, where the coal will be loaded on barges and shipped to Portland.

The Oregon Coal and Timber Company, Joseph Gaston, president, W. T. Webber, superintendent, has obtained possession of the old Idleman mine, situated in Secs. 12 and 13, T. 9 N., R. 2 W., about a mile and a half east of Castle Rock. The mine was first opened up by Mr. C. M. Idleman, a number of years ago. It was worked in a small way until 1893, when it closed down on account of litigation. The new company began operations late in the autumn of 1901. The old workings have been pumped out and preparations are now being made to develop the mines on an extensive scale. Several veins are being opened up, one four feet six inches, another four feet one inch, and a third six feet in thickness, respectively. Still other veins of unknown thickness outcrop at points below. A standard gauge railroad from the mine to the Cowlitz river is partly completed. An incline seven hundred feet in length has been driven and a number of crosscuts made. The coal is a brown lignite with very little sulphur and a small percentage of ash. It will be shipped in barges to Portland.

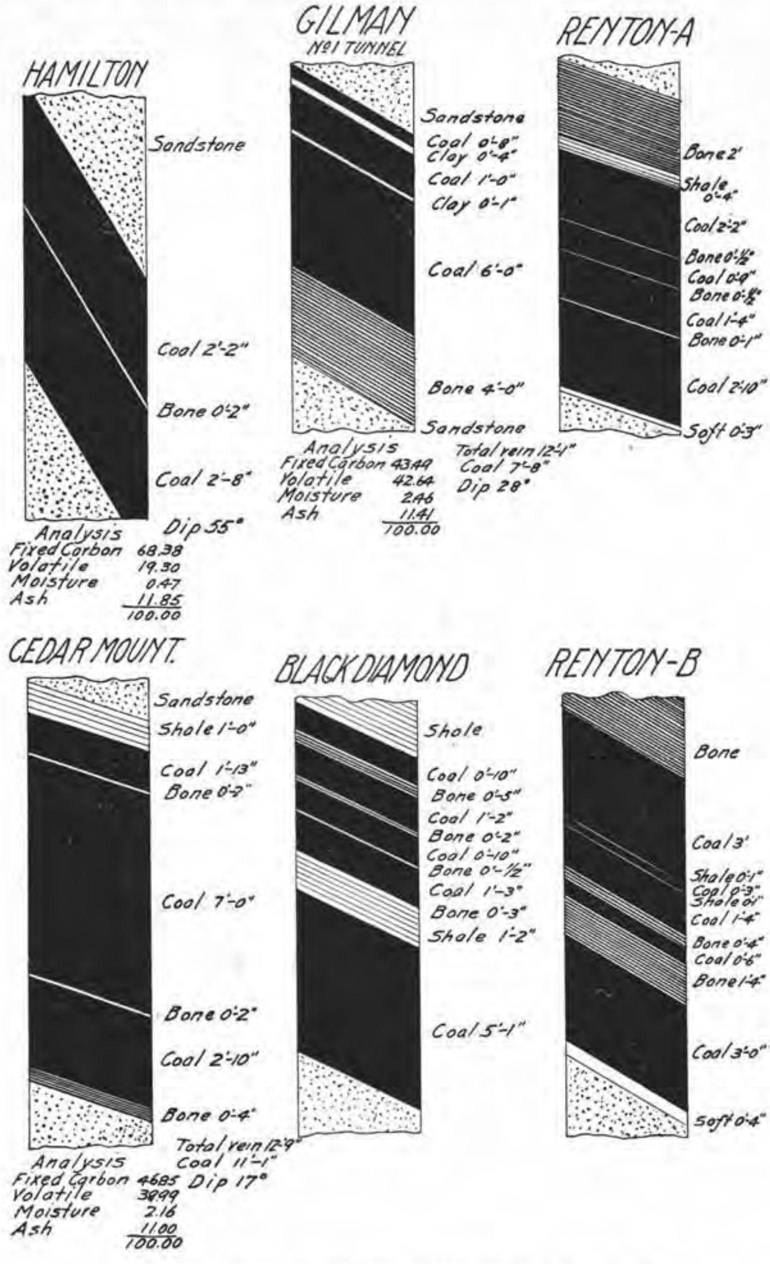
Another mine known as the Red Ash mine was opened up several years ago on Arkansas creek, about two or three miles west of Castle Rock. A considerable amount of coal was shipped to Portland and other places, where it is said to have given good satisfaction. It was closed down about two years ago, but negotiations are now pending whereby it will be opened again. The vein that was worked is said to be seven feet in thickness. A shaft has been sunk and an incline one hundred and fifty feet in length driven on the vein.

The Carbondale mine, three miles southeast of Castle Rock, in Sec. 24, T. 9 N., R. 1 W., has been developed to some extent. It belongs to Portland parties. No coal has yet been shipped from this prospect.

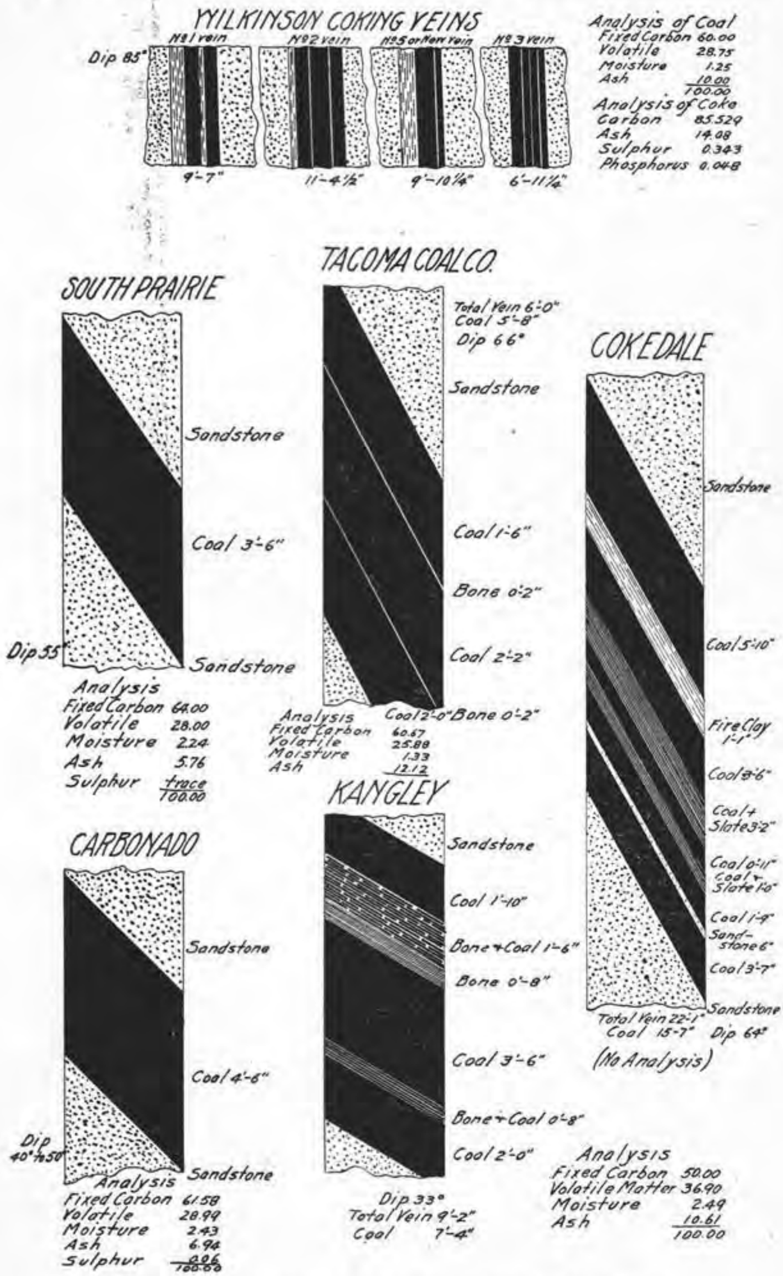
Another prospect upon which work has been done lies in the NW. ¼ Sec. 24, T. 10 N., R. 1 W., on Toutle river, three or four miles from the Cowlitz. Other prospect holes have been sunk on Sec. 24, T. 9 N., R. 1 W., and in Secs. 8 and 18, T. 10 N., R. 1 E.



SECTIONS OF COAL SEAMS, WITH COAL ANALYSES.



SECTIONS OF COAL SEAMS, WITH CO L ANALYSES.



SECTIONS OF COAL SEAMS, WITH COAL ANALYSES.

PART V.

THE WATER RESOURCES OF WASHINGTON.

POTABLE AND MINERAL WATER.

BY H. G. BYERS.

ARTESIAN WATER.

BY C. A. RUDDY.

WATER POWER.

BY R. E. HEINE.

LAKE WHATCOM.

BLUE LAKE, NEAR OROVILLE

THE WATER RESOURCES OF WASHINGTON.

POTABLE AND MINERAL WATER.

By H. G. Byers.

CITY WATER SUPPLIES.

Water surveys have been or are being made in many of the states. These surveys are for the purpose of determining the sanitary condition of present supplies, of the formulation of standards of purity of unpolluted waters, and of enabling citizens to gain immediate and authoritative information in regard to the potability of any source of supply. These surveys are made at the expense of the state and are in some cases of great extent and corresponding value.

That an abundant supply of pure drinking water is very important for the preservation of health, and that impure water is a most potent factor in the development and spread of disease, are propositions the truth of which is unquestioned by physicians, scientists or the general public. It is not a matter of general information, however, that local conditions greatly modify the deductions to be made from a given analysis, and that such results as would in certain circumstances indicate unsanitary water would in other cases indicate no such condition. For example results which if obtained from the water of deep wells would indicate certainty of contamination would carry no such significance if the water were from surface drainage.

The water supplies of the state are from three sources—rain, deep wells, and surface drainage; this last includes shallow wells and springs. Of these surface drainage waters are by far the most important since but few people use rain water directly and but few deep wells have been sunk. The report in this case therefore deals only with surface waters.

We were led into this investigation by the fact that, when recently arrived in the state, we were called upon to pronounce upon the purity of the water of the city of Chehalis. It was then learned that there were no records of analyses upon which to rest a comparison, and therefore no local data upon which to base a decision. No funds were at our disposal yet we nevertheless started to accumulate such data and deeming that the most valuable imformation was to be gleaned from the investigation of the city supplies, our work was almost exclusively upon them.

In making these analyses we omitted no reasonable precaution to secure results which are accurate and conclusive. The waters, where possible, were collected by ourselves, and in all other cases careful instructions were given to persons who collected the samples for us. As soon as possible after the receipt of a sample the analysis was begun and was usually completed upon the same day. The methods of analysis were those employed by the Massachusetts Board of Health or by the Illinois State Survey. Nearly all the samples were collected between November 15, 1900 and May 1, 1901, and so represent winter conditions. The results of similar analyses of summer waters would add greatly to the value of the report.

The results were surprising in many cases because of the great purity of the waters, and hence it seemed interesting to compare our results with similar analyses of the water supplies of eastern cities. These were obtained from New York, Chicago, St. Paul, Minneapolis, New Orleans, Boston and other places. No results could be obtained from San Francisco and Portland because no analyses have been made. St. Louis failed to send any results. The value of such work is shown by the fact that the city of Chehalis now secures its supply from a purer source and the city of Ballard will probably secure an extension of the Cedar river system which furnishes the supply of Seattle. It is clear also from our analyses that the limits of potability as laid down by the Illinois survey for the waters of that state do not hold here. The results of our analyses are given in the accompanying table.

The results which are given in parts per million are in terms which, for the most part, are unintelligible to the general public, therefore a discussion of them is necessary.

It is well known that water in nature is never pure, but contains in solution various substances upon the character and quan-

TABLE OF SANITARY ANALYSIS OF POTABLE WATERS, IN PARTS PER MILLION.

LOCALITY.	Date.	Sediment.	Color.	Taste.	Solids on evaporation. Volatile.	Non-volatile.	Total.	Nitrogen as— Nitrites.	Nitrates.	Nitrogen as ammonia. Free.	Albuminoid.	Oxygen consumed.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	Remarks.
University of Washington	Feb. 18, 1901	None.	Very clear	None	27.12	29.86	87.08	None	.030	.010	.055	4.40	2.60	2.35	49.82	52.17	Supply from surface springs.
University of Washington	Mar. 15, 1901	None.	Slightly brown	None	30.34	70.28	100.62	None	.384	.012	.036	4.74	5.40	4.40	42.24	46.64	Residue blackened upon heating.
Seattle, city	Feb. 8, 1901	None	Very clear	None	23.00	110.00	133.00	None	None.	.070	.023	1.40	4.40	5.00	65.00	70.00	Cedar river water. Had not washed out pipes. System in short time.
Seattle, city	Mar. 13, 1901	None	Very clear	None	12.50	23.60	36.10	None	.032	.048	.011	1.31	2.50	1.22	15.90	17.12	Cedar river water.
Seattle, city	April 27, 1901	None	Very clear	None	10.50	25.99	36.49	None	0.000	.008	Trace.	1.26	1.50	1.49	12.32	13.81	Cedar river water.
Tacoma, city	Feb. 23, 1901	None	Slightly brown	Little flat	22.00	25.20	47.20	None	0.000	.035	.080	6.34	4.40	0.00	50.00	50.00	Clover creek and springs.
Tacoma, city	April 4, 1901	None	Slightly brown	None	30.78	31.39	62.17	None	.080	.026	.0827	7.63	3.25	3.44	9.77	13.21	Residue blackened upon heating.
Mineral Spring (Ravena Park)	Feb. 28, 1901	None	Very clear	Not pleasant.	33.55	105.83	139.38	None	.380	.400	.045	2.71	4.40	0.00	80.07	80.07	Smells of hydrogen sulphide. Contains trace of sulphur.
Lake Washington	Mar. 9, 1901	Some	Brown	None	24.85	32.70	57.55	None	.130	.010	.095	7.25	4.00	1.18	34.64	35.82	Brown from suspended matter. Residue blackened on heating.
Chehalis, city	Nov. 15, 1900				109.50	130.90	240.40	.098	7.190	.090	.088	2.88	24.80	20.00	75.00	95.00	Residue blackened on heating. Supply condemned.
Newaukum river	Nov. 25, 1900	Considerable	Clear	None	50.00	33.00	83.00	None	0.000	.030	.055	8.57	4.80	1.00	2.50	3.00	———
Everett Water company	Jan. 10, 1901	Some	Turbid	None	48.00	252.80	300.80	None	0.000	.020	.050	7.27	4.80	5.00	150.00	155.00	———
Snohomish, city	Feb. 23, 1901	None	Clear	None	18.28	23.22	41.50	None	.400	.010	.093	3.75	4.00	0.00	40.00	40.00	———
Whatcom, city	Mar. 16, 1901	None	Very clear	None	42.34	116.52	158.86	None	0.000	.004	.033	2.03	3.80	0.00	68.78	68.78	———
Elder's well, Fremont	Mar. 22, 1901	Considerable	Cloudy	None	41.20	150.02	191.22	None	.260	.003	.092	1.35	4.00	4.80	68.61	73.41	Deep artesian well.
Ballard, city	Mar. 25, 1901	Considerable	Very clear	None	43.75	121.91	165.66	None	.320	.874	.100	2.89	5 50	44.68	26.10	70.78	Residue blackened upon heating.
University Heights, Seattle	Mar. 10, 1901	Considerable	Cloudy	None	26.75	75.00	101.75	None	.840	.013	.0063	.559	5.25	13.77	40.71	84.48	From a deep artesian well.
Mineral Spring (Bremerton)	April 3, 1901	Considerable	Clear		45.37	311.79	257.16	None	.290	.066	.1407	6.28	31.00	1.72	1.18	2.90	Residue blackened on heating. Gave an odor of burning garbage, probably due to sulphur.
North Yakima, city	April 8, 1901	Slight	Slightly roily	None	54.68	114.85	169.53	None	0.000	.008	.0177	1.79	2.75	11.19	80.23	97.42	———
Walla Walla, city	April 12, 1901	None	Clear	None	18.81	62.86	81.67	None	.452	.008	.0267	2.89	1.50	0.00	22.68	22.68	Residue blackened on heating.
Aberdeen, city	April 14, 1901	None	Clear	None	12.50	63.19	75.69	None	.090	0.000	.021	.966	6.50	0.00	13.81	13.81	———
Olympia, city	April 20, 1901	None	Clear	None	26.64	80.86	107.50	None	.050	Trace.	.0323	3.38	4.20	11.83	28.59	40.42	———
Spokane, city	April 23, 1901	None	Slightly whitish	None	15.81	34.43	50.24	None	.018	.004	.0363	2.13	1.50	0.00	12.33	12 38	Residue blackened upon heating.
Port Townsend, city	Feb. 16, 1901	Very little	Very clear	Brackish	343.00	830.10	1,173.10	None	2.544	.010	.063	1.52	462.40	67.57	101.92	169.49	Residue blackened upon heating. Solids—sea salt.
Brooklyn (Miss Hansee's well)	Jan. 10, 1901	None	Clear	None	82.50	111.00	192.50	None	6.80	.030	.047	1.90	14.40	85.00	25.00	110.00	Residue blackened upon heating.
Brooklyn (Meredith's well)	Mar. 16, 1901	Some	Cloudy	Flat	47.07	123.17	170.24	None	None.	.371	.095	2.80	14.00	7.02	85.15	92.17	Water smells foul. Residue blackens upon heating.
Fremont (S. A. Graham's well)	Mar. 22, 1901		Clear		119.06	149.91	268.97		8.51	.005	.047	0.27	48.00	None.	93.67	93.67	Well under house. Suspicious.
Ballard (Paul Hopkins' well)	April 8, 1901		Clear		30.95	71.95	102.90	None	4.90	.007	.068	2.03	9.50	1.72	21.80	23.52	———
Seattle (Denny-Fuhrman school)	Sept. 25, 1901		Clear		61.00	132.50	193.50	None	0.00	.050	.030	1.50	8.00				———
Port Townsend (Glendale dairy)	Sept. 28, 1901	None	Clear	None	85.36	153.64	239.00	None	6.94	.200	.187	22.12	46.75	93.05	53.32	146.37	Residue blackened upon heating.
Brooklyn (Mr. Cudworth's well)	May 11, 1901		Clear	None	36.68	102.04	135.72			.1728	.0266	1.40	7.75	4.43	64.08	68.51	———
Everett (private well)	Jan. 22, 1901	None	Clear	None	50.00	42.50	92.50	None	None.	.070	.055	4.50	13.6	0.00	40.00	40.00	———
																	———
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New York, city (Croton R.)	April 11, 1901		Slightly turbid		21.00	43.00	64.00	None	.424	.035	.160		2.35	0.00	27.40	27.40	———
New York (Ridgewood water)	April 10, 1901		Slightly turbid		35.00	64.00	99.00	None	2.014	.005	.057		22.00	0.00	37.80	37.80	———
Chicago (Lake Michigan)	Feb.8-11, 1901									.018	.020	1.62	3.31				Daily analysis of Chicago water.
Chicago	Dec. 26, 1896	Very little			6.00	134.40	140.40	.001	.150	.003	.080	2.50	3.00				———
Boston	April 4, 1898	Slight	Slightly turbid		17.50	15.50	33.00	None	.070	.016	.178	5.70	3.00				———
Minneapolis	Dec. 25, 1900	Moderate			53.00	186.00	239.00	None	Trace.	.100	.225	8.45	2.10				———
St. Paul (Lake Vadnais)	Sept. 2, 1899				71.00	102.00	173.00	None	.030	.064	.176	6.00	.50				———
St. Paul (Artesian wells)	Sept. 2, 1899				58.00	214.00	272.00	None	Trace.	.252	.005	1.00	1.25				———
St. Paul (Lake Peltier)	Sept. 5, 1899				120.00	91.00	211.00	None	.040	.062	.595	16.20	1.425				———
New Orleans	April 2, 1901	Considerable	Turbid				956.00	.003	.180	.001	.347	12.70	7.70				———

tity of which depends the potability of water. Rain water as it falls from the clouds is probably the purest obtainable without distillation, but even this contains dust particles and gases washed out of the air. As soon as water reaches the earth it begins to dissolve more or less of all the substances with which it comes in contact, becoming impure with harmless, harmful or beneficial ingredients. In well peopled regions the water courses are often simply sewers which convey away or assist in the destruction of the refuse organic matter of the surface. Springs many times contain besides the mineral matters over which they pass, some of the vegetable or mineral matters through which the water has percolated in reaching their sources. In the case of wells contamination is usually due to the nature of the soil in which they are sunk, but may be added to by the infiltration of sewage from cesspools or privy vaults which not infrequently are situated in close proximity to the wells. In such cases the purifying influence of the earth is relied upon, but which, while undoubtedly great, is very frequently over estimated.

The fact that the water of a given source of supply is clear, is as is well known, no certificate of its purity; though lack of clearness, while not a certain indication of *dangerous* contamination, is certainly not a desirable condition. It is true also that clear sparkling water contaminated by sewage may sometimes be used for a long time without harm to the users. No one, however, would knowingly use such water simply as a matter of taste, yet there is the additional fact of the constant danger of the introduction of germs of contagious diseases where the contamination is of animal nature. Such being the case water which is impure with, or subject to contamination from, matter of animal origin is more dangerous than water rendered foul with decaying vegetable matter. In the latter case, however, an excessive amount of impurities is not considered healthful and is to be considered as rendering a water unfit for use. From all these facts it is clear that it is necessary for an analyst, in order to form the most useful conclusion from the result of his analysis to know as much as possible about the history of the water involved, the nature of the soil through which it passes, and the location of surrounding sources of infection.

All waters, except in special cases, contain the same substances and it is upon the varying quantities of these that a judgment is based. The substances usually sought in a chemical analysis, *i. e.*, those which bear relation to sanitary conditions and the amount which it is possible for a water to contain and remain fit for drinking purposes are given in the subjoined table, which is taken from the report of the Illinois Survey:

	Parts per million.
Total solids	500.
Loss on ignition (no blacking should occur and no offensive odor develop)	....
Oxygen consumed	2.
Chlorine	15.
Nitrogen as free or saline ammonia	0.02
Nitrogen as albumenoid ammonia	0.05
Nitrogen as nitrites	0.001
Nitrogen as nitrates	15.

These figures are of course only approximate, even for Illinois, and are but a good general guide. It is to be noted that judging by our analyses the limit for chlorine and nitrates is several points too high, while the limit for ammonia content is too low.

The total solids of a water are not of very great importance unless they are in such quantity as to be detrimental because of that fact or because of their nature as determined by subsequent analysis. The loss on ignition is of water, which may have been chemically combined with the salts present, of carbon dioxide from the carbonates or ammonia salts, or of animal or vegetable matter. The last item is the one of prime importance, and blackening of what is otherwise a white residue is indicative of organic matter, which if of animal origin is likely to develop an offensive odor and give the analyst a clue to the nature of the contamination. The fixed residue consists of harmless or beneficial salts. A sample analysis is given below. The nature and quantity of the organic content of a water is of much greater importance. This consists of living or dead organisms of animal or vegetable nature, of fœcal matter and the products of decomposition of animal matter. There is no direct means of determining their nature and amount because in the process of determination they undergo change. But all organic matter may be burned; that is, made to unite with oxygen, and consequently the amount of oxygen consumed when water is treated with oxidizing agents is, if always determined in the same way, a guide to the relative amount of organic matter present.

More important is the fact that nitrogen is a constituent of all living matter, and its determination in the four forms in which it may exist in water offers the best and most accurate means of study of those substances which render water unsanitary.

Nitrogen as albumenoid ammonia represents the amount of nitrogen present in the form of undecomposed organic matter. This may consist of animal tissues, urea, fœcal matter, etc., substances which serve as food for micro-organisms of vegetable or animal nature and which includes the disease bacteria. The presence of much nitrogen in this form in usually indicative of sewage pollution or drainage from refuse animal matters. The quantity is likely to be normally larger than the limits given in the preceding table where the water passes over such quantites of nitrogen bearing vegetable matter as in this region.

Nitrogen as free ammonia represents the nitrogen either as free ammonia or in combination with acid residues and which usually proceeds from nitrogenous organic matter which has decayed without the presence of considerable quantities of inorganic substances. It may be looked upon as proof of the existence of organic matter in the first stages of decay.

Nitrogen as nitrites represents the decomposition products of organic matter under the influence of living organisms, so that its presence is evidence not only of organic matter but of living germs as well.

Nitrogen as nitrates represents the complete oxidation of the nitrogenous materials, and its presence in large amount signifies that the water if not now dangerous has been so and is still open to suspicion. Indeed our work seems to show that a much smaller amount than fifteen parts per million would in this region indicate contamination.

The chlorides present in water serve for determining the purity of the water only if the location of the supply is known.

Water may contain large quantities of salt and still be free from organic contamination, though whether still good for constant consumption is a doubtful question. This is the case with water of Port Townsend. The source of the chlorine there, as is evident from the location of the pumping station, is seepage from Puget sound which of course contains large quanties of chlorides. Chlorine is however a constant constituent of urine and excrement and, other things being equal, the presence of an unusual amount of it in water is proof positive of sewage contamination.

The hardness of water is of no special sanitary importance; but since, generally speaking, the harder a water the less fit it is for domestic purposes, the relative hardness, expressed as if it were all due to calcium carbonate is a guide to the culinary and cleansing qualities of water.

The inorganic or fixed residue is never analyzed for sanitary purpose, unless the presence of some poisonous substance, as lead, is suspected. Its analysis is a guide to the usefulness of water for boiler purposes. For practical purposes the scale forming portions may be considered as made up of items 4, 5, 6, and 7 of residue analysis given below. Sometimes quantities more or less considerable of magnesium and other chlorides are present, and these are undesirable because of their corrosive action on boilers. Occasionally residue analyses will reveal the presence of ingredients of medicinal value. These will be referred to under the head of mineral springs.

RESIDUE ANALYSIS OF CEDAR RIVER WATER.

	Grams per liter (parts per thousand)
Total solids	.03117
Volatile solids	.00786
Non-volatile solids	.02331
Silica	.00178
Alumina and oxide of iron	.00492
Calcium sulphate	.00514
Calcium carbonate	.01666
Magnesium chloride	.00149
Sodium chloride	.00063

A comparison of the analyses given above reveals the fact that our cities have exceptionally pure water supplies. This is particularly true of Seattle, Tacoma, Everett, Spokane; our largest towns. They have their supplies from mountain streams and lakes which drain water sheds free from injurious contamination and to this they owe their purity.

In a country of such rank vegetable growth and heavy rainfall we would naturally expect the water to be somewhat impure. Indeed, the few analyses of surface waters made by us accord with that expection. See the analyses of wells and springs given in foregoing table.

The character of our city supplies will be sufficiently outlined by a brief description of those of Seattle, Tacoma and Spokane. Seattle obtains its supply from Cedar river at a point twenty-eight miles from the city. The river which flows into Black river is the outlet of Cedar lake, which drains an area of two hundred square miles, all of which is under the control of the city, so that its purity is assured. The water is conveyed to the city from the intake, by gravity alone, to the high service reservoir, whence a portion is pumped by means of the surplus water to the stand pipe on Queen Anne hill, which supplies the highest parts of the city. The amount of water now conveyed to the city is about twenty-five million gallons per day, while the maximum available supply is approximately three hundred millions, a quantity sufficient to supply a population of one and a half million on the basis of one hundred and fifty gallons per capita. The reservoirs at present in use in the city have a capacity of approximately fifty million gallons.

The city of Tacoma obtains its supply from Clover creek, a small mountain stream, and from springs. These are gravel bed springs and, as is true also of Clover creek, are not affected by local rainfall. They together can furnish a maximum daily supply of twelve million gallons per day of exceptionally pure water.

Spokane obtains its supply from the Spokane river, which drains all the north and west slope of the Coeur d'Alene mountains. The supply is pumped to the city from a point about five miles above the city, and now supplies to the city about eight million gallons per day.

These supplies, because of their purity and the ease with which they are conveyed to the users, compare very favorably with that of even Chicago, which pumps its enormous supply of 160 gallons per capita per day from Lake Michigan, the purity of which in the neighborhood of the intake is improved by the sewage canal connecting the lake with the Illinois river. The local supplies are very much of an improvement over those of St. Paul, Minneapolis, New Orleans and other cities.

MINERAL SPRINGS.

The mineral springs of the state are numerous but have not been developed to any very great extent. There are hot springs at Madison on the Great Northern Railway, and at Green River Hot Springs on the line of the Northern Pacific. At both of these places sanitariums have been built and have become considerably frequented by seekers after health and pleasure. The

Madison hot springs were visited by Mr. H. G. Knight, in concection with this work, and some data in regard to them were obtained. Similar data in regard to the Green River springs were requested, but were not furnished by the owners. The Madison springs are on the mountain side just west of the tunnel on the Great Northern. The water comes out of fissures in the mountain side some six hundred feet above and a mile and a half back of the location of the sanitarium. The supply is sufficient to fill a two-inch pipe, and is at the spring at a temperature of about 112° F. The following analysis was made by Mr. C. Osseward, chemist for Stewart & Holmes Drug Company, Seattle:

RESULTS EXPRESSED IN GRAINS PER GALLON.

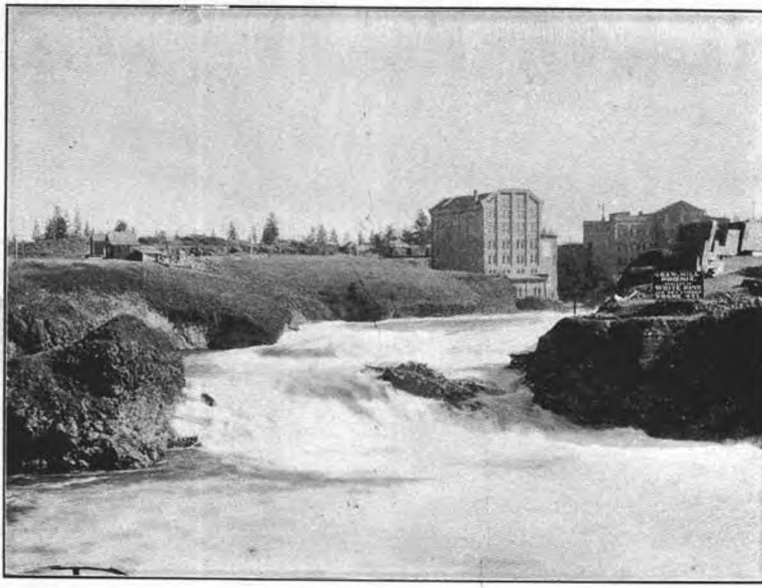
Total solids	9.9	Silica	1.34
Chlorine	0.87	Sodium	1.63
Iron	0.76	Potassium	0.34
Lime	2.33	Sulphuric anhydride	0.52
Magnesia	1.1	Ammonia	0.00058

There are also mineral springs at Cascades in Skamania county, which have a daily flow of thirty thousand gallons. During 1901 7,000 gallons were sold for medicinal use, and about 120,000 gallons were used for bathing purposes. A sample of the water could not be obtained for analysis in time for this report.

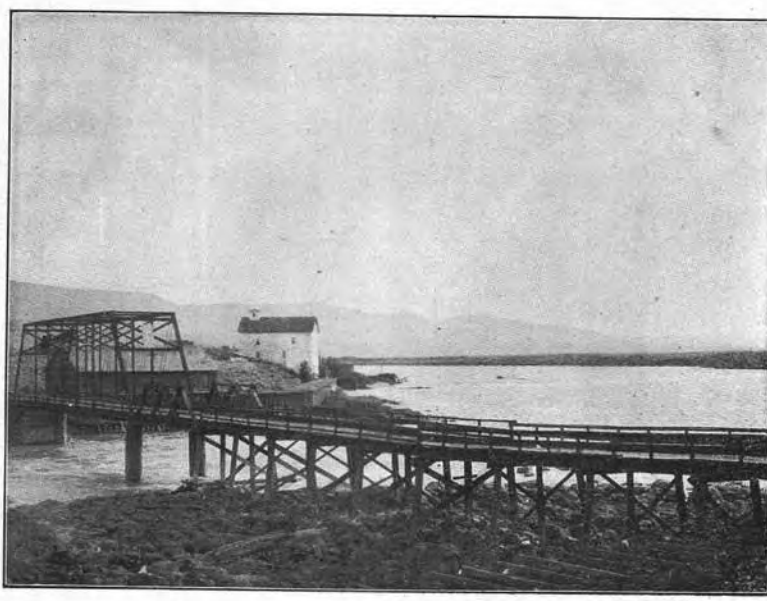
The waters of Medical lake in Spokane county are acquiring a reputation for curative properties, and an analysis of the water made by G. A. Mariner, of Chicago, is appended.

	Parts per thousand.
Silica	0.1825
Alumina and iron oxide	0.0120
Calcium carbonate	0.0031
Magnesium carbonate	0.0040
Sodium chloride	0.2869
Potassium chloride	0.1616
Sodium carbonate	0.1089
Potassium carbonate	Trace.
Lithium carbonate	Trace.
Borax	Trace.

Near Skykomish on the bank of the river about a half mile from the little town of Berlin, are some very interesting springs. They are saturated with carbon dioxide, and when the nearly ice-cold water is allowed to stand in vessels it effervesces vigorously. The flow from the larger of the two springs is estimated at from two to three gallons per minute. Both are chalybeate



FALLS OF THE SPOKANE RIVER, SPOKANE.



FALLS OF THE YAKIMA RIVER, PROSSER.

springs and have made considerable deposits of iron around their mouths. The analysis of the water is given.

	Parts per thousand.
Solids, non-volatile	0.5473
Silica	0.0078
Alumina and iron oxide	0.0150
Calcium sulphate	0.0529
Calcium carbonate	0.5627
Magnesium chloride	0.1693
Magnesium sulphate	0.0935
Sodium sulphate	0.9331
Potassium chloride	0.0267
Carbon dioxide	1.4720

There are also mineral springs, warm and cold, in the Yakima Indian Reservation on Simcoe creek about fifteen miles from Fort Simcoe, but at the season of the year when this report was compiled it was impossible to get full information in regard to them.

By the kindness of Mr. Joseph Parrott, of Glenwood, we have considerable information regarding a rather large number of hot springs and cold mineral springs along the Klickitat river, south of Mount Adams. These seem of such interest that an effort will be made to carefully investigate them and include the report upon them in a future report of the survey.

Near Bremerton there is a mineral spring which was formerly a favorite resort of the Indians who not infrequently camped near it to obtain renewed health and vigor. Its analysis shows ingredients which render probable its medicinal value. Analysis by H. G. Knight:

	Parts per thousand.
Non-volatile solids	0.45194
Silica	0.01334
Alumina and iron oxides	0.04764
Calcium sulphate	0.046385
Magnesium chloride	0.04008
Magnesium sulphate	0.07790
Sodium sulphate	0.23686
Lithium sulphate	0.02128

ALKALI LAKES.

The alkali lakes of the state are neither numerous nor large. Among the largest are Moses lake, Blue lake and Sanitarium or Soap lake. These together with numerous temporary ponds and a chain of fresh water lakes occupy the former bed of the Columbia — the Grand Coulee.

Moses lake, which lies about twelve miles southeast of

Ephrata on the Great Northern Railway, is about eighteen miles long and a mile wide, and is very shallow. The average depth is approximately twenty feet. It lies in a shallow basin with low banks, so that a rise of but a few feet would inundate a large section of country. The water is unfit for drinking purposes, but is not strongly alkaline and could probably be used in irrigation. The section of country in which these lakes are located is, of course, very dry and supports only a scanty vegetation. Where there is water, however, the soil is very fertile. The lake drains a large area through upper Crab creek. It has no outlet but across its foot lies a low range of sand hills through which the water seeps into the sources of lower Crab creek, which occupies the bed of the canyon below. Along this canyon lie numerous shallow ponds which dry up in summer. The deposits left by these are not of any considerable value, though they contain an appreciable quantity of borax.

An interesting feature of Moses lake is the fact that it is gradually rising, having risen about ten feet in the last seven years. If it continues to rise through a few more feet it will break through a clear course into lower Crab creek and empty into the Columbia.

The analysis of the water of Moses lake is as follows. The analysis is by H. G. Knight:

	Parts per thousand.
Total solids	0.32357
Volatile solids	0.10095
Non-volatile solids	0.22262
Silica	0.01502
Alumina and iron oxide	0.00331
Calcium carbonate	0.06235
Magnesium carbonate	0.07525
Sodium sulphate	0.01258
Sodium chloride	0.01895
Sodium carbonate	0.10914

More interesting is the so-called Soap lake, or Sanitarium lake, situated about six miles north of Ephrata. This lake is so-called because it is so strongly alkaline as to be soapy to the touch, and when a strong wind blows across it the water along the shore is beaten into great rolls of foam. Fish can not live in the water, nor is there any vegetation in this as in Moses lake. The water is used for bathing, but to those unaccustomed to its use the water has a slightly caustic or irritating effect. It is also claimed that it is useful medicinally. There is much of peculiar interest about the lake. It is about two and a quarter by three-quarters miles in extent and is very deep in places and probably averages about forty feet. It drains only a very small area of country and has neither inlet nor outlet in the form of streams. It is located in a deep basin walled to the height of one hundred feet or more on the east and west by cliffs of black basalt. The land to the north and south rises slowly; on the south to nearly the height of the cliffs, but on the north the rise is so slight that should the lake rise fifteen feet it would empty in the next of the chain of lakes to the north. The source of the water of the lake is said to be a spring in the center. The Indians of the neighborhood assert that only a few years since the lake was very small and was fed by this strongly alkaline spring. Fresh water is however continually seeping in from the shores, as is shown by the fact that fresh water wells may be sunk even but a few feet from the shore, and that the cattle disliking the strongly alkaline water face the shore to obtain the sweeter seepage. The water of the lake contains calcareous matter to such an extent that the stones and debris at the bottom are incrusted with a frost-like coating of calcium carbonate.

The analysis of the water is as follows:

	Parts per thousand.
Total solids	28.2669
Volatile solids	0.62503
Non-volatile solids	27.64186
Silica	0.12816
Alumina and iron oxide	Trace
Calcium sulphate	Trace
Calcium carbonate	Trace
Magnesium sulphate	0.39099
Sodium sulphate	6.34872
Sodium chloride	5.81384
Sodium carbonate	14.08901
Potassium carbonate	0.51177
Lithium sulphate	Trace
Phoshorus pentoxide	0.12018
Carbon dioxide (semicombined)	1.37034
Borax	None
Iodine	None
Free ammonia	.03400
Albumenoid ammonia	1.1060
The specific gravity	1.0260

A more extended investigation of the waters of the state would be of value. This is especially true of the mineral waters, which have indeed received but scant attention.

The greater part of the work and most of the analyses represented in this report are due to Mr. H. G. Knight.

ARTESIAN WATER.

By C. A. Ruddy.

INTRODUCTION.

The fundamental principles governing the flow of artesian water are simple and readily grasped by anyone. It is only an illustration of the well known fact that "water seeks its own level." The prime requisite is to have a water-bearing stratum overlaid and underlaid by impervious strata, and to have its surface outcropping at a higher elevation than the surface of the ground where the proposed well is to be sunk. Although so simple theoretically, yet practically the problem has many factors by no means easy of solution.

Our knowledge of the conditions underlying the surface of the earth is very imperfect at best. Usually the surface outcropping of the strata are more or less obscured by a mantle of soil, so that it is often difficult to determine accurately the dip of the rocks or their exact physical structure. The ideal conditions of a synclinal valley with clearly defined strata outcropping on its elevated edges as usually figured in the text-books seldom occurs in nature; the actual conditions are not necessarily more complex, but they are more obscure.

In studying the formation of the rocks in any locality with a view to the possiblity of obtaining artesian water it is well to know just how much dependence can be placed on surface indications. Strata which at their outcrop may have all the appearances of being good water-bearers may at a short distance below the surface of the ground change into perfectly impervious strata, without in any way breaking the continuity of the beds. This change in structure may be either favorable or unfavorable, according to the other conditions of the basin. Likewise the strata above or below the water-bearer may at their outcrop be perfectly impervious and yet change in their nature so much that at the locality where the well is to be sunk they will not hold water at all.

Strata are not usually continuous over wide areas. They are more or less lenticular in shape, being usually thickest towards the center and gradually thinning out as the edges are approached. The same bed may change from coarse to fine, from conglomerate to sandstone, and even to shale.

When the rocks of a region have been greatly folded and faulted there is not much use trying to find artesian water in them. This does not apply to long, open folds unaccompanied by fracturing, but to close folding and crushing, caused by great lateral pressure. The fact that the rocks are in such a distorted condition shows that they have been subjected to enormous pressure, which would have the tendency to compress them so much that they would lose most of their water-carrying properties. Their position, too, would usually preclude the possibility of water being carried any distance under ground. Where rocks in this condition occur it is impossible from surface indications to determine where water would likely be found.

It is useless to look for water in the older crystalline rocks, such as granite, gneiss or schist, so that when in drilling a well rocks of this nature are encountered, there is no use going any deeper.

When the drilling of a well for artesian water is contemplated, the geological structure should of course be carefully worked out as far as surface indications will permit. Very often the pervious stratum, on account of its unconsolidated or friable condition, is more easily eroded than the enclosing beds, so that it is more likely to be found in the bottom of a valley than forming the hill tops. When such a valley floor is at a greater elevation than the surface of the ground where the proposed well is to be sunk, this position of the outcrop is more favorable than otherwise, because it permits of the water being held over the surface of the outcrop for a greater length of time, and thus gives more of it a chance to soak into the rocks. The area of surface exposed of the water-bearing bed should also be taken into considration when estimating the probable quantity of water taken into the rock. The area multiplied by the annual rainfall will give the total amount of water which falls on the outcrop, but it must be borne in mind that not all the water which falls as rain soaks into the rock. A part of it runs off in the streams or is taken into the air again by evaporation. The drier the region the less the amount carried off by streams and the greater the amount lost by evaporation. Sometimes the outcrop, as in the case of the valley mentioned above, receives the drainage of surrounding areas, and thus its available supply is augmented. The porosity of the rock at its surface will of course also have its share in determining what proportion of the rainfall is absorbed by the rocks and what escapes by other means. These considerations are of most importance in arid regions where the wells, even if succcessful, are liable to fail in time, owing to the inadequate supply.

An ordinary red brick will absorb its own weight of water. Coarse grained sandstones absorb water very readily, except where the spaces between the grains have been filled in by material carried there in solution. The finer the grains the less readily will water pass through. Fine shales and clays are almost entirely impervious, so that in an artesian basin they make a good upper and lower layer to keep the water from escaping.

The water may escape either upward or downward by means of fissures in the enclosing beds. Surface outcroppings give little indications of the existence of such defects, but in a general way it may be said that the less the beds are consolidated and the less they have been upturned from their original horizontal position, the less likely they are to be fissured. Limestones, when not fissured, are usually quite impervious, but they are more likely than any other rocks to contain underground channels, so if they form either of the enclosing beds of the supposed water-bearing stratum, they should be viewed with considerable suspicion.

Theoretically, the water should rise in the wells as high as its own head, but as a matter of fact it never does. The frictional resistance offered by the rock through which the water passes, and to a lesser extent, that offered by the walls of the well itself, has the effect of reducing the height of the column of water. The difference in height between the water in the well and at its source in the rock is greater or less depending upon the texture of the rocks, the amount of leakage, the distance the water has to come, and to a much lesser extent, the diameter of the well. Rocks of fine texture offer a very much greater resistance to the passage of water than those of coarse texture. The larger the diameter of the well the less the resistance offered to the ascending column of water. The discrepancy between the theoretical height of the water and its actual height can not be accurately determined beforehand, but allowance should always be made for it. This is particularly necessary where the head is not very great.

In some of the older geological formations of the eastern states the strata are often continuous over thousands of square miles, but in this state none of the geological formations have strata continuous over wide areas. The sedimentary beds change from coarse to fine and thin out rapidly. This goes to show that it is hazardous to assume what the conditions are below the surface from the appearance of the outcrops, even a few miles away. To the practical man looking for artesian water in this state we would say, pay less attention to the character of the rock at its outcrop than to its dip. By a careful study of the dips and elevations good artesian conditions can often be discovered. Whether the rocks are pervious or impervious is largely a matter of guess work until a well has been actually sunk and the facts ascertained.

In a large number of places in the arid regions of central Washington it is not possible to obtain water for irrigation purposes by means of canals, owing to insufficient water in the streams. In these localities the only salvation lies in finding artesian water. It is perhaps too much to hope that it will be found over very wide areas, but by careful investigation new localities may be found where the position of the rocks would justify the attempt.

By referring to the chart issued annually by the United States Weather Bureau, showing the annual precipitation in different parts of the state, it will be seen that there is a large area in central Washington between the Cascade mountains and the Columbia river, and for some distance east of that stream, where the annual rainfall is less than eighteen inches. While eighteen inches per annum is usually considered the minimum amount with which agriculture can profitably be carried on, yet there are a number of conditions of soil and climate which vary this amount for different regions. Soil which is made up largely of sand or gravel or has either of them for a subsoil quickly loses its moisture and dries up. In certain parts of western Washington south of Puget sound where the annual precipitation is very heavy, there are soils of this nature on which the scanty vegetation withers up during the first few hot days of summer.

On the contrary, within the big bend of the Columbia, known as the "Big Bend Country," the soil is a deep, rich loam formed by the decomposition of the underlying basalt. The rain and snow of winter and early spring soak through the soil and fill up all the crevices of the rocks. Then when the dry weather comes these act as reservoirs and the water is gradually brought to the surface by capillary attraction and made available for the crops. In the country about Waterville, where these conditions occur, good crops are produced with an annual rainfall of about thirteen inches.

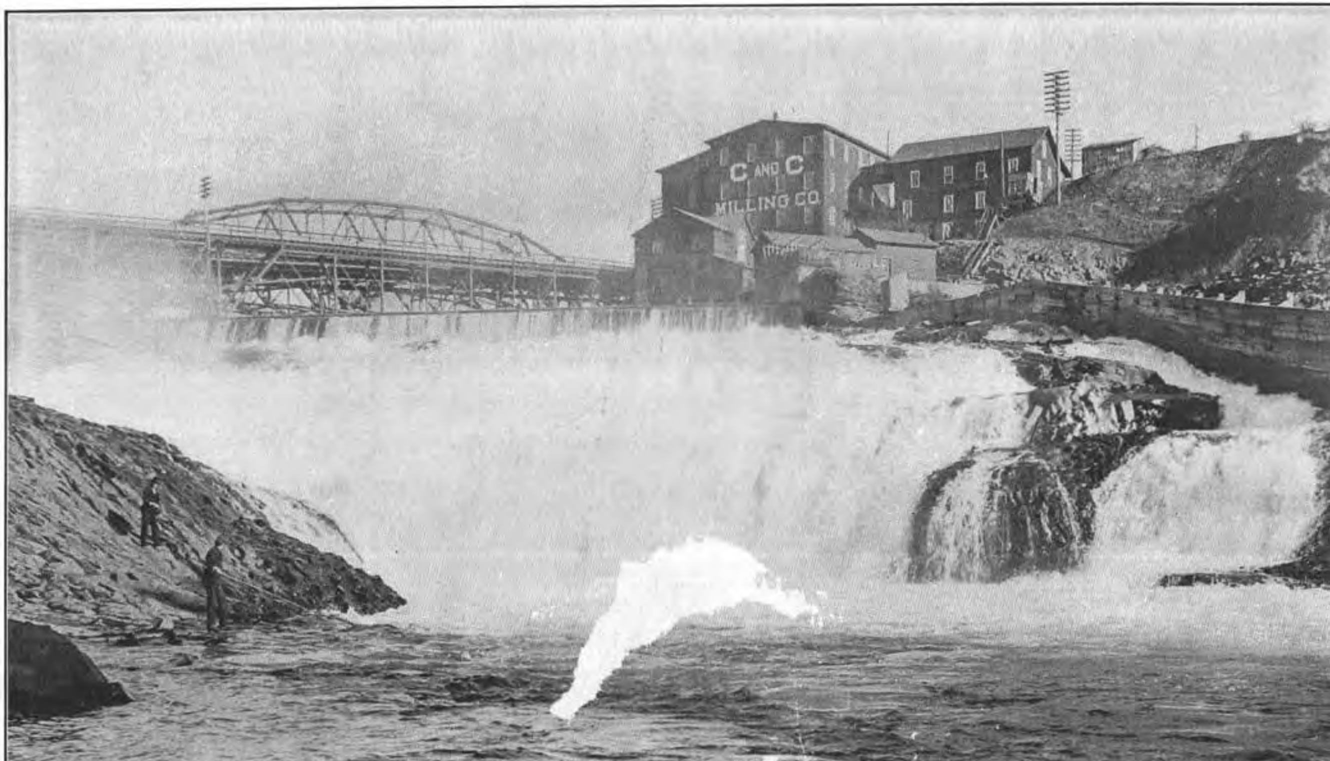
Where the rainfall is scanty it makes considerable difference how it is distributed throughout the year. To be of most use for crops the rain should come during the growing season. Where this is the case comparatively little rain will suffice.

Artesian water is of course of most value in arid regions, especially if the quantity is sufficient for irrigation. For this reason more attention ought to be paid to its exploitation in regions where the rainfall is light than where it is sufficient for agriculture. Nevertheless a good flowing well is of value almost anywhere.

YAKIMA VALLEY.

In this state the greatest progress in developing the artesian water supply has been made in the Yakima valley.

The oldest rock which outcrops in this valley is the Columbia lava, of Miocene age. It forms part of the great lava field which covers southeastern Washington and Oregon and extends southward and eastward into Idaho, Nevada and California. In Yakima county it is made up of a succession of flows varying in thickness from a few feet to a hundred or more, the line of contact between the layers being usually very well marked. Some layers show a marked difference in jointing from those above and below. The rock is a very dark basalt, usually quite compact, but often more or less vesicular. In many places beds of volcanic tuff are found between the basalt flows. Basalt, in its molten state, is one of the least viscous of lavas. When in its liquid state it is poured forth from a vent, instead of building up



FALLS OF THE SPOKANE RIVER, SPOKANE.

a cone it spreads far out as a nearly horizontal sheet. For this reason we find no volcanic cones in the Columbia lava field. Each flow found its way to the surface through a fissure which was afterwards covered up by succeeding flows. The interval of time between successive flows in this region must have been in some cases many years, and even centuries. Sufficient time elapsed for soil to form and forests to grow thereon before being overwhelmed by the next overflow. This is shown by the presence of charred wood between the flows of lava.

During the long ages in which the older rocks were becoming more and more deeply submerged by the molten flood, there was little folding or tilting of the rocks in this region. The Cascade mountains were very much lower than at present, especially in the southern part of the state. When the outflows of basaltic lava had almost ceased, there came a change, so that the region now forming the valley of the Yakima formed part of the bed of a great fresh-water lake. This lake existed so long that sediments more than a thousand feet in thickness were deposited on its bed. It was a time of great volcanic activity, as shown by the character of the sediments. These are largely volcanic ash and broken fragments of pumice. The eruptions which furnished this material were largely of the explosive type, rather than the quiet outflows which characterized the formation of the Columbia lava plain. Along the ancient shore line conglomerate beds occur, made up of boulders of light-colored andesite and other volcanic rocks. The great variations of the beds show that the oscillations of the land were comparatively rapid and irregular. Sometimes the water of the lake would recede and the streams would cut rapidly into their soft sediments; then the waters would encroach again and new sediments would be spread out, leveling off the old irregularities.

At intervals throughout the period in which the lake sediments were accumulating, there came belated outbreaks of basaltic lava which spread out over the soft sediments. These were the last convulsive signs of life of those great volcanic forces which were active throughout a great part of the Miocene period and which caused the formation of the Columbia lava fields, the greatest body of lava in the known world.

After the lake was finally drained the greater part of the sediments were carried away by erosion, but remnants still remain. They form the light-colored sedimentary beds outcropping in places in the Yakima valley and about its borders. These are the rocks in which artesian water has been found. They form what is known as the Ellensburg formation, and are of Miocene age, as shown by the fossil leaves preserved in them. The most extensive outcrops are seen along the Natches river and at White Bluffs, on the Columbia.

At the close of the period just described, the region to the westward was gradually uplifted so as to form the Cascade mountains. At the same time or later, a series of low east and west folds were formed between the Columbia river and the Cascades, nearly at right angles to the axis of the mountain range. The ridges are not due to faults, as formerly supposed; they are all anticlines, while the valleys between them are synclines. Atanum creek occupies one of these synclines, and the Natches river another. The crests of the ridges have been almost entirely denuded of the Ellensburg beds, so that only the basalt is left. One of these, known as the Selah ridge, borders the Yakima valley on the north, and another, the Yakima ridge, borders it on the south. The Yakima river has cut gaps through the ridges and crosses them at right angles. It evidently had its course established before the folding began; then as the folds arose slowly the river kept pace with them, cutting down its channel.

At some period later than the Miocene, a great stream of lava came flowing down from somewhere between the headwaters of the Nachez and Tieton rivers, covering the hills and obliterating the valleys. It reached as far east as the mouth of the Cowiche creek and then stopped. The rock is a very dark andesite. It forms a conspicuous landmark, standing as bold cliffs on the lower Tieton and at the junction of Cowiche creek with the Naches river. It is safe to say that nowhere on the surface of this lava can artesian water be found. It stands at too high an elevation, and any water contained in the beds below would find a readier outlet by means of springs along the base of the cliffs where the andesite meets the underlying rocks.

As shown by the geological map, the Ellensburg beds extend westward a mile or two beyond Tampico postoffice and occupy practically all of the valley below that point. The city of North Yakima stands at an elevation of about 1,067 feet above sea level. Ellensburg beds have been traced twenty miles west of that point to an elevation of 2,350 feet. On the hills north of Tampico postoffice they outcrop as beds of conglomerate, sandstone and volcanic ash, dipping slightly to the eastward.

North Yakima had a total precipitation in 1900 of 7.22 inches. To the westward as the mountains are approached the precipitation increases. It seems probable that most of the water which finds its way into the strata falls upon the western border of the Ellensburg, and gradually finds its way down into the the lower part of the valley.

The two synclines occupied respectively by the Naches river and Atanum creek in their upper valleys gradually merge into one as they approach the Yakima river. Where the Yakima has cut its way across the valley there is only one syncline. On both the north and south sides, parallel to the longer sides of the valley, the beds dip towards the valley at a steep angle. On the eastern and western sides they dip more gradually. The valley is underlaid by Ellensburg beds to a depth of over a thousand feet, while along the elevated edges it has all been eroded away, leaving the bare basalt ridges.

A large part of the rain which falls on the ridges is absorbed by the rocks as soon as it reaches the porous beds at the base of the hills. Along the western border of the basin the tops of the hills are at such an elevation as materially to increase the rainfall. Atanum creek flows over the Ellensburg beds for a number of miles, and from measurements made of its volume at different places along its course, it is evident that a considerable part of it is absorbed by the rocks.

The part of the valley east of the Yakima river is known as the Moxee valley. It is here that nearly all of the artesian wells are located. There are now more than thirty wells within an area of six square miles. The following table, taken from the report of Mr. George Otis Smith on the Geology and Water Resources of a Portion of Yakima County, Water Supply and Irrigation Papers of the United States Geological Survey, No. 55, gives most of the important information concerning these wells:

LIST OF WELLS IN ATANUM-MOXEE BASIN.

Number	NAME OF WELL.	Location. Section	Location. Township	Location. Range	Approximate elevation	Depth	Flow	Depth to principal flows.				Temperature of water
					Feet.	*Feet.*	*Sec. ft.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Deg. F.*
1	Clark No. 1	6	12	20	1,110	940	1.34	700	(?)	(?)	(?)	73.2
2	Clark No. 2	31	13	20	1,130	1,026	.15	800	(?)	(?)	1,000	76.2
3	Clark No. 3	31	13	20	1,120	1,000	.52	......	......	......	......	75.6
4	Longevin No. 1	8	12	20	1,070	637	.40	637	......	......	......	72.2
5	Haines	8	12	20	1,145	902	.984	702	760	790	902	72.2
6	Bradford	9	12	20	1,155	623	.904	386	......	623	......	73.2
7	Dickson	8	12	20	1,095	525	*.......	515	......	......	......	70.7
8	Gano	8	12	20	1,075	851	*.......	649	......	851	......	76.0
9	Sauve	8	12	20	1,155	1,020	.475	832	(?)	(?)	1,020	75.2
10	Ellens. No. 1	7	12	20	1,065	835	.13	835	......	......	......	73.2
11	Holland No. 1	5	12	20	1,100	736	†2.00	588	688	736	......	76.0
12	Regimbal	5	12	20	1,105	689	1.09	525	640	686	......	73.2
13	Buwalda	32	13	20	1,150	653	.05	424	508	550	600	67.2
14	Ellens. No. 2	8	12	20	1,100	676	*.......	424	504	657	......	....
15	Buwalda and Haines	5	12	20	1,140	636	†.566	475	575	636	......	69.2
16	Holland No. 2	5	12	20	1,115	686	.35	520	620	686	......	74.7
17	Clark No. 4	31	13	20	1,140	960	.197	660	770	820	......	73.2
18	Allwardt	9	12	20	1,185	809	.64	......	{615 ‡to 718	}752	......	72.2
19	Deeringhoff	4	12	20	1,165	625	....	390	......	625	......	73.2
20	Rein	10	12	20	1,195	631	.485	+630	......	......	......	66.3
21	Hill	4	12	20	1,170	225	....	206	......	......	......	....
22	Longevin No. 2	8	12	20	1,080	836	.807	530	(?)	820	......	72.7
23	Peck	6	12	20	1,105	818	†1.10	620	(?)	818	......	....
24	Wilson	29	13	18	1,165	1,267	§.75	800	1,000	1,050	......	80.0

* Well closed April, 1901.
† Approximate measurement with current meter.
‡ Six flows.
§ Estimated.

It is estimated that the total area irrigated by these wells amounts to about 1,650 acres. Some of them are said to be decreasing in volume, and in some instances even to have ceased flowing altogether. This may be due to caving of the wells due to improper construction. It is quite possible, of course, that the basin may now be developed to its full capacity, so that the drilling of more wells would not increase the total flow. If such were the case, the water which would flow from new wells would simply decrease by that much the amount which flowed from the other wells. Heretofore the wells have been allowed to flow freely throughout the year, but at the last session of the State Legislature a law was passed compelling owners of wells to keep them closed from the 1st day of October in any year until the 1st day of the following April. This does not prevent the use of water for stock or for domestic purposes. The effect of this law will be salutary in preventing the waste of water during the season when it is not necessary for irrigation, and will greatly increase the capacity of the basin. The amount of land in this part of valley which can be brought under cultivation is limited only by the supply of water.

On the western side of the Yakima river the demand for artesian water is not so urgent. A number of canals bring water from the Naches river, and supply all the lower part of the valley. Other canals utilize the waters of Atanum creek. Up to the present time only one artesian well has been drilled west of the Yakima. This is on the farm of Mr. George Wilson, in Wide Hollow, and irrigates about fifty acres. It is important as showing the presence of artesian water in this part of the valley, so that the problem is simplified for any one who in the future wishes to sink a well in the same locality.

KITTITAS VALLEY.

In the Kittitas valley, in which the city of Ellensburg is situated, the same geological formations occur as in the Yakima valley farther south. Its basin-like structure, however, is not so clearly marked. The valley is underlaid by the Ellensburg formation to an unknown depth. On every side of the valley the enclosing hills are of basalt. The Yakima river flows through the valley from northwest to southeast and escapes through a deep notch cut in the enclosing ridge. A well was sunk in the valley a number of years ago and is said to have reached basalt at 700 feet. Water came up within 40 feet of the surface. Mr. Smith, in the report previously referred to, is of the opinion that the chances of obtaining artesian water are sufficiently favorable to justify the drilling of another well.

WHITMAN COUNTY.

About the only other locality in the state where an artesian basin has been developed is in Whitman county. Flowing water has been struck at a number of places in the county, but the most important basin lies within the town of Pullman. This locality is within the limits of the Columbia lava field, but is not more than a dozen miles from its eastern border, where the lava lies against the flanks of the mountains of western Idaho, which are composed of ancient crystalline rocks. At several places north and south of Pullman there are isolated buttes of crystalline rock entirely surrounded by the lava, which represent the highest peaks of the ancient land surface which was submerged by the lava. Steptoe and Kamiack buttes are the most conspicuous. In Snake river canyon, a few miles to the southward, sections of the lava are exposed, which Russell* has estimated to be as much as 5,000 feet in thickness. This goes to show the extreme ruggedness of the old topography. The lava sheets have been upturned only in a very slight degree from their original horizontal position. Between some of the layers of basalt there can be seen the evidence of forest growth, showing that a considerable interval of time must have elapsed, in some cases at least, between the successive flows. In some places beds of sand occur between the sheets. These probably indicate the courses of streams which flowed over the lava during the interval between flows. The sand beds act as reservoirs for the storage of artesian water.

At Pullman there are about a dozen flowing wells in the lower part of town. In putting down these wells the drillers first penetrated a layer of basalt and finally reached sand at a depth of seventy or eighty feet. Flowing water was found in the sand. These wells have now been flowing for a number of years and do not show any diminution in volume. Besides a number of private wells, the city has one from which the whole town is supplied.

At the town of Palouse, Whitman county, there are four flowing wells. The geological conditions are the same as at Pullman. Black basalt was first penetrated and water found in the underlying sand.

It is evident that little can be foretold as to where water is likely to be found in the Palouse country. The rocks are so nearly horizontal that it is difficult to identify a basin. The beds of sand are of limited extent and usually do not outcrop on the surface. The most favorable positions for sinking wells, of course, are the lowest parts of the valleys. There is a wide extent of country where flowing waters are liable to be found. The rainfall in this part of the state is sufficient for agriculture and good non-flowing wells for domestic purposes can be found almost anywhere, so that the finding of artesian water is not of such vital importance to the welfare of the community as it is in the arid region to the westward.

*Russell: Water Supply and Irrigation Papers, No. 4, U. S. Geol. Survey.

The arid and semi-arid region of the state includes all of Douglas, Franklin and Adams counties, the eastern parts of Kittitas, Yakima and Klickitat, the western halves of Lincoln and Walla Walla, and parts of Okanogan and Chelan counties. In certain parts of this region, as in the vicinity of Waterville, farming is carried on with more or less success, but water is used for irrigation wherever it is possible to get it. By far the greater part of this arid region is very sparsely inhabited, and is so dry that it is not fit for grazing purposes, except during a few short weeks in spring. The average annual rainfall for the last ten years varies in different parts of the region from six and a half to sixteen inches. The available water in the streams is sufficient to irrigate only a small proportion of the total area, even when utilized to its fullest possible extent.

In the region west of the Columbia river, it is not unreasonable to expect that the artesian conditions which exist in the Moxee-Atanum valley may be duplicated in other places where the geology is somewhat similar. South of the Moxee-Atanum valley the country between the Cascade mountains and the Columbia is traversed by several east and west ridges similar in appearance to those to the northward whose structure has been shown to be anticlinal. If these southern ridges are also anticlines, which seems probable, the troughs between them ought to form artesian basins. Priest rapids, on the Columbia, marks the point where one of the east and west ridges has been upraised across the course of the Columbia. A careful study of the structure of these southern valleys would be necessary in order to determine whether or not it was worth the while to drill in them for water. East of the Columbia the conditions will probably be found to be somewhat different. The streams are nearly all small and have cut deep trenches in the basalt plateau. They can irrigate only small patches at best, and they usually run dry at the season when they are the most sorely needed. Where not too deeply dissected, artesian water may be found in isolated areas throughout this region in basins similar to those discovered in Whitman county.

WATER POWER.

By R. E. Heine.

INTRODUCTION.

Washington contains the greatest amount of water power of any state west of the Mississippi. The extremely heavy rainfall of the Cascade and Olympic mountains supplies the water for a large number of short, swift rivers which come tumbling down out of the mountains with a fall, in many instances, of several thousand feet in a very few miles. The Cascade mountains have been very appropriately named; everywhere along the upper reaches of the streams which head in these mountains one can see foaming cataracts and cascades alternating with stretches of more quiet water. The aggregate potential power contained in these streams is inconceivably great. The snow accumulates in the mountains to great depths in winter and melts off gradually during the summer, thus insuring a fairly uniform volume of water throughout the year.

In western Washington the greatest floods usually occur in December or the latter part of November. These are due to the heavy autumn rains which come at a season when the temperature in the mountains is not low enough to convert the moisture into snow. Again in the latter part of May, or early part of June, there are floods in all the rivers flowing down from the mountains. The floods are brought about at this time by the rapid melting of the snow during the first few hot days of summer. These floods are especially high in the tributaries of the Columbia and in that river itself. Cloudy weather during April and May, followed by a very dry, hot spell, will send all the rivers booming, and the floods are frequently very destructive. In western Washington the spring floods are not so high as they are along the eastern slope of the Cascades and in the Okanogan highlands. The climate of western Washington is more equable; there are no rapid changes from one extreme to the other, such as we find east of the Cascades, and therefore the snow melts at a more uniform rate. The streams gradually decrease in volume as summer advances until the fall rains come again. In

HEAD-WORKS OF SNOQUALMIE FALLS POWER COMPANY.

August and September they are at their lowest. All of the larger streams which head in the Cascade and Olympic ranges have at least some of their tributaries fed by glaciers. In the late summer after all the snow has disappeared from the exposed mountain sides and even the sheltered ravines, the glaciers on the highest peaks still continue to feed the streams which issue from them.

In estimating the available water power of a stream the calculations are of course based on the volume of water which the stream carries when it is at its lowest. In many cases where the stream gets too low, storage reservoirs could be built.

The Columbia river is the master stream of all eastern Washington. It has a minimum volume of about sixty thousand cubic feet per second, and in its course through the state has a total fall of about thirteen hundred feet. In a number of places along its upper course power could no doubt be taken from it. Many of its larger tributaries are rapid streams with immense undeveloped water power. In some places, as at Spokane falls on the Spokane river, and at Prosser falls on the Yakima, the power is already being utilized.

The western slope of the Cascade mountains is approximately parallel to the axis of the valley of Puget sound and its southern extension to the Columbia. This valley region is the most populous part of the state and is rapidly taking rank as a manufacturing center. Power for street railways, for electric lighting, and for all kinds of manufacturing purposes is necessary, and the problem of the cheapest way of obtaining it is one whose solution has great practical bearing upon the future welfare of the community. The great plant installed by the Snoqualmie Power Company at Snoqualmie falls will serve as an object lesson and an example of what can be done along this line. The number of places in western Washington where plants similar in kind but smaller in size could be installed is very large.

The Blue mountains lie in the extreme southeastern corner of the state. The annual rainfall on these mountains is from twenty-two to twenty-four inches. After the last of the snow melts upon their summits in the spring there is a long dry season, during which the streams get very low. For the greater part of the year, however, they possess an abundant water power which could be utilized for many purposes. Some of the streams have already been harnessed, as in the case of Mill creek from which the city of Walla Walla derives power.

SNOQUALMIE FALLS.

The great falls of the Snoqualmie river are situated in the western foothills of the Cascade mountains, about 25 miles east of Seattle, and 34½ miles northeast of Tacoma. The river proper commences about three miles above the falls, at the junction of three tributaries whose origin is in the snow fields of the Cascades. The flow of the river is about 1,000 cubic feet per second during the driest season, and about ten times as much during the periods of high water. The river has a vertical drop of 270 feet at the falls, giving a minimum available energy of 30,000 horse-power.

The present plant is somewhat unique in its construction, inasmuch as the water wheels and electrical machinery are installed together in a large underground chamber, whose floor is directly above the tail-race tunnel which extends to the river below the falls.

A shaft 10x27 feet has been sunk into the rock about 300 feet above the falls, and at the bottom of this is excavated out of the solid rock a cavity 200 feet long by 50 feet wide and 30 feet high, and from this cavity a tunnel serving as tail-race extends to the foot of the falls.

The water is received from the river through a masonry intake and conducted down the shaft to the water wheels through a steel pipe seven and one-half feet in diameter.

The generating plant consists of four electric generators, each driven by a Doble water motor of 2,500 horse-power coupled directly to it. Two exciters of 75 kilo-watt each and one elevator operated by a water wheel complete the power equipment. The generators deliver current at 1,000 volts, which is raised to 30,000 at the transformer station above the power house.

The Snoqualmie Falls Power Company furnishes power for both lighting, railway and general power purposes, and it is expected that many of the manufacturing plants of Seattle and Tacoma will soon be operated by Snoqualmie power. At Issaquah, Renton and Auburn, power is used for lighting. In Seattle all the stationary motors, the entire municipal street-lighting system, several large mills and half of the street railways are operated by Snoqualmie power, while at Tacoma all the lighting circuits, street railways and many motors are run from the same source.

The plant now installed develops a total of 10,000 horsepower. A transmission line to Everett, 35 miles distant, is proposed, where a smelter, paper mill and other factories are expected to be operated by electricity. By the erection of a 50-foot dam above the head works, a reservoir having an area of 15 square miles and average depth of 25 feet could be formed. This would almost double the power, should the demand call for it. The shaft will accommodate another penstock of the same capacity as the present one, and both intake and tail-race have been built for double the capacity. Another chamber and additional machinery are the only extensions necessary to double the capacity of the plant, and these have been under consideration by the company.

The Snoqualmie Falls Power Company does not engage in the distribution of power to small customers, but sells power in large quantities to customers at moderate prices. The Seattle Electric Company and Seattle Cataract Company are among the largest consumers, using nearly two-thirds of the total power generated.

SPOKANE FALLS.

Within the city limits of Spokane, and in close proximity to the manufacturing center, a series of falls are encountered by the Spokane river, aggregating a total of about 130 feet. The Washington Water Power Company owns and controls practically all of the available water power at that place, and furnishes power, either in the form of electric energy, or by leasing a part of the water supply to parties wishing to use the same.

A portion of what is called the "lower falls" is at present used for the development of power, and a number of flumes have been built from a dam 200 feet wide, situated at the head of these falls, to a power house located about 600 feet below this dam. The available head of water is 70 feet, which after reduction for height of water in the tailrace, is reduced to an effective head of 68 feet. The flumes are built of steel, of circular cross-section; two of them are each seven feet and one ten feet in diameter. The velocity of the water in the flumes is approximately six and one-half feet per second, and with the present electrical equipment about 5,300 horse-power are carried on the switchboard.

The power generated is used for the operation of the street cars, the lighting of the street lamps, stores and private residences, and furnishing power to the various manufacturers in the city.

During the past year the Washington Water Power Company has installed two 1000-horse-power generators, one for operating the street railway system and the other for lighting and power purposes.

The conditions for development of additional water-power at Spokane are decidedly favorable. The capacity of the falls exceeds the demand. During the driest months of the year the quantity of water discharged at the falls is never less than 2,000 cubic feet per second. The present equipment of the plant utilizes scarcely 1,000 cubic feet per second, or scant fifty per cent. of the available water, which goes to show that the output of the plant can be doubled by additional flumes without increasing the head.

The Washington Water Power Company has already completed plans for the addition of two flumes, each ten feet in diameter, for the operation of a long-distance power-tansmission line to the Coeur d'Alene mining district, about ninety miles [illegible] of Spokane.

[illegible] Coeur d'Alene region is one of the great mining centers [illegible], and the operation of the various types of mining machinery calls for a large amount of power, which has been found most suitable and flexible in the form of electricity.

The proposed transmission system is to be three-phase with a step-up transformer station at the power house, the line pressure to be 45,000 volts. Two pole lines are planned for one circuit each, copper conductors, although until the demand for power requires it, but one circuit will be put up.

By the addition of this machinery the total output of the pl[illegible] will be increased to very nearly 13,000 horse-power, and wi[illegible] enable the company to supply light and power to parties in the vicinity of the transmission line.

In spite of the fact that Spokane is subject to considerable extremes of temperature, the Spokane river never freezes up and anchor ice is unknown, nor is the variation of head between the tail-race and head falls very large. These two facts permit a closer regulation of the water-wheels than is the case in many water-power plants.

Should conditions demand it, the great natural reservoir, Coeur d'Alene lake, could be used as a storage reservoir, whereby the output of the plant would be increased by about 25 per cent. The Washington Water Power Company has not found it necessary to develop the power of the upper falls, which would yield an additional head of 60 feet of water. The company, however, will lease portions of these falls to parties desiring to develop their own power, or will furnish them with electric power directly, which might be a more simple proposition for an intending customer.

It is only a question of time when the manufacturing industries of Spokane will have reached a stage when nearly 20,000 horse-power will be required. The total available horse-power has been variously estimated, but in all probabilities does not fall below 30,000.

MILL CREEK, NEAR WALLA WALLA.

In the spring of 1901 the Walla Walla Gas and Electric Company completed a water-power plant for the supply of electric current to Walla Walla. The plant is situated five miles east of the city on Mill Creek, and is operated on the monocyclic system supplemented by a rotary steam engine.

Mill creek has its origin in the Blue mountains and is subject to rapid fluctations. The minimum flow is 2,800 cubic feet per minute during extreme dry weather, but the average is considerable higher.

The water is taken from the creek at a point 5,600 feet above the plant, where a concrete dam is built. The water is conveyed to the plant through a four-foot stave pipe built of redwood, the actual head at the power house being 85 feet. The pipe is buried in the ground for the entire length and has shown but little depreciation during a period of seven years.

A 27-inch Morgan-Smith turbine of 450 horse-power is directly connected at a 300 kilo-watt G. E. generator. A 400 horse-power rotary steam engine, of the Thomas and Brumagin type, is belted to generator shaft, provided with a Hill clutch, so that the generator can be operated either by water, steam or both.

The plant has been run on a 24-hour per day service since May 1, 1901, and has been in continuous operation without a single shut-down or accident.

PROSSER FALLS, YAKIMA RIVER.

The town of Prosser, in the eastern part of Yakima county, is favorably located for the development of water-power for irrigational and manufacturing purposes. Both of these have been attempted, but have not been carried out to the full capacity of the available water-power in the Yakima river. The river has a fall of about twenty feet at Prosser, and during the dry season the discharge is about 2,000 cubic feet per second, from which nearly 5,000 horse-power could be obtained.

At present the Yakima Falls Roller Mills and the Prosser Irrigation Company are the only users of water-power at that place. The former operate a small mill, using about 50 horse-power, while the latter company have already taken steps for the utilization of most of the water. A small electric light plant of 30 horse-power is also in operation, but this will be supplanted by the contemplated improvements of the Prosser Falls Irrigation Company.

This company has now in operation two pumps, each of 4,000 gallons per minute, used for irrigational purposes. Each pump is driven by a Victor turbine, forty-eight inches in diameter, capable of developing 135 horse-power, and the two combined deliver water through a 28-inch steel pipe, 2,900 feet in length, to the canal, 112 feet above the surface of the river. The irrigation canal has two branches, one three miles and the other seven miles long and is capable of irrigating nearly 2,000 acres.

The company is contemplating the addition of another pump for the purpose of supplying the city with an adequate waterworks system, and an electric generator to supply the town with light and power. There is also a scheme on foot for the construction of an electric railway from Prosser on toward Yakima, the power to be generated at Prosser falls. In that event it will be necessary to either build a dam to increase the fall, or to go some distance below the falls in order to obtain sufficient head of water, as the present pumping station is worked at a head of only twelve feet.

The prospects for an increased demand of power and water at Prosser and vicinity are very favorable, a larger electric lighting plant being now almost a necessity. The Prosser Falls Irrigation Company controls the entire south side of the river, on which the town is situated, and is prepared to install machinery for parties contemplating the use of power.

CHELAN FALLS.

One of the large and still undeveloped sources of water-power of the state can be found in the Chelan river, which is the outlet of Lake Chelan, and flows into the Columbia river. The river is about three and a half miles long from Lake Chelan to the Columbia river, the total fall being 375 feet, distributed through the whole distance in a series of rapids and low falls. About one-third of the total fall occurs within a distance of half a mile, where the river flows through a box canyon. It is only thirty or forty feet wide in places, rushing down between rocky walls 300 feet high.

The cliff recedes at one point, leaving ample room for a large power station. In the two and a half miles from the lake to the canyon, the fall is quite regular, and power plants could be located at many places. The only existing plant at present is a 40-barrel flour mill at Chelan falls near the mouth of the river.

No accurate measurements of the water supply have been made, except those of some local parties, which show that the minimum flow is from 1,200 to 1,500 cubic feet per second.

The Chelan Transportation and Smelting Company expect to erect an electric plant very soon, the capacity of the plant to be about 500 horse-power. This plant will be used for the operation of their smelter and an electric railroad from the smelter, situated on the Columbia river, to the lake. The company expects to have the cars in operation during the latter part of 1902. The chief use of the railroad will be the transportation of ores from the numerous mines in the vicinity to the smelter, the capacity of which will be about 500 tons per day.

There is a good opportunity for flouring mills to be operated by water-power, the wheat crop of the entire "Big Bend country" being at their very doors.

Irrigation can also be developed to a considerable extent, there being over 3,000 acres of land waiting for water. All that is required is the necessary capital for the operating plant.

As mentioned before, no thorough investigation of the resources of water-power have been made at this place, and one can safely predict an industrial center at Chelan should the same ever be developed to the full capacity.

PURITAN MINES, NEAR LOOMIS.

The Puritan mines are situated on a stream known as Toats coulee, a rushing mountain torrent, which encounters a fall of about 300 feet within the located water right of the mining company. At the lowest stage of water the supply is sufficient to develop fully 1,000 horse power, which would be ample for all necessary mining and milling operations on their property.

At present two Pelton water wheels are installed, one driving a 50-horse-power Ingersoll compressor, and the other operating a saw-mill utilizing about 60 horse-power.

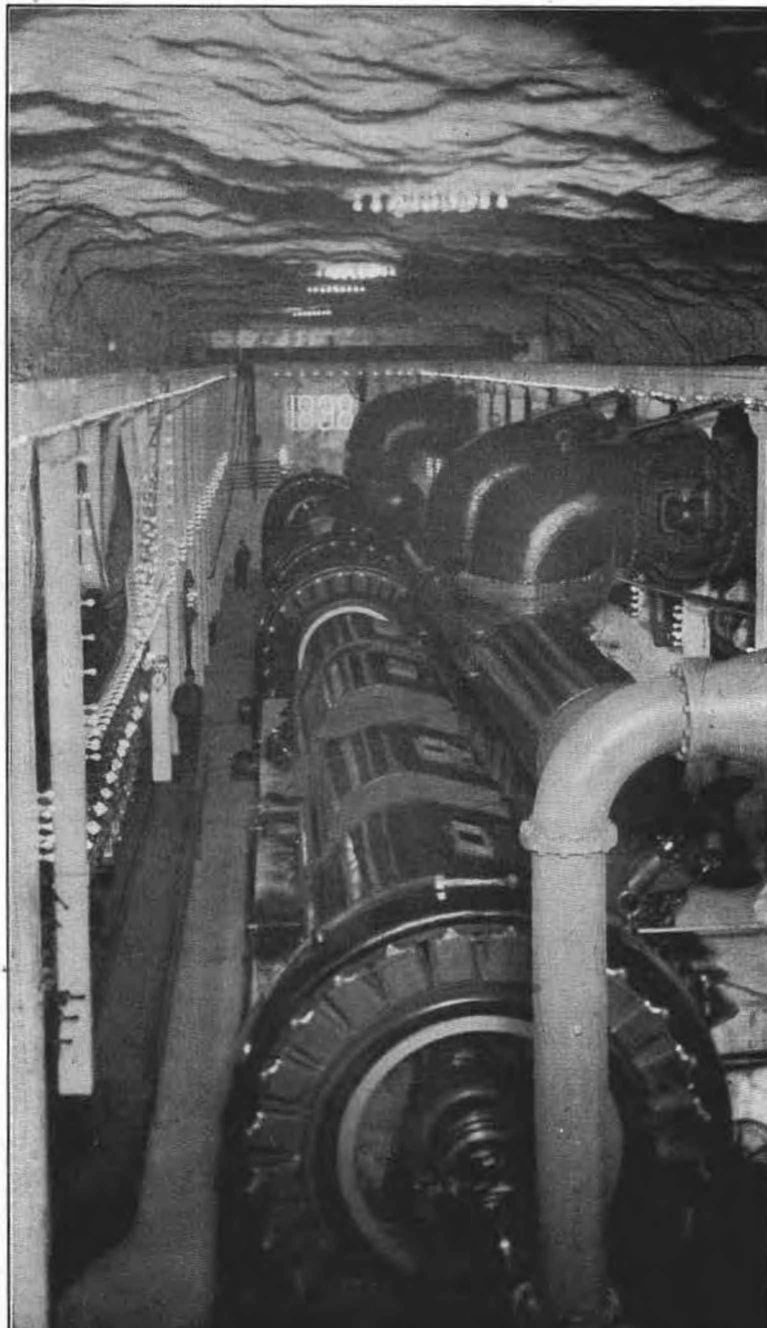
Future developments in the mining and milling industries at this locality might make the development of additional water power necessary, for which, however, there is an abundant supply in the stream mentioned above, the total head of water which might be utilized being nearly 1,000 feet.

WHATCOM FALLS.

Lake Whatcom, having an area of about eight square miles, is situated nearly three miles from Bellingham bay, and its mean elevation is about 318 feet above tidewater. Whatcom creek, the outlet of the lake, empties into the bay in the city of Whatcom. The water-power of this creek consists of three main falls, the first occurring about half a mile from the lake, the next half a mile below this one, and the last just before the stream enters Bellingham bay. This last fall is now developed and is used for the operation of a large lumber mill.

For the first two miles the stream is very rapid, the banks steep and the average width of the stream not over forty feet. The river bed shows in many places to be of solid rock, and ought not to add any difficulties for the foundations of any power plants. The total head of water from the lake to bay is about 315 feet, of which 150 feet occurs in the upper two falls.

No accurate measurements of the amount of water discharged have ever been taken, but rough measurements by various parties show that the minimum flow is about 140 cubic feet per



INTERIOR OF SNOQUALMIE FALLS POWER STATION.

second. The watershed which drains this lake contains no less than sixty square miles. By building a dam at the outlet of the lake, which can be done without great difficulties, the level of the lake might be increased four or five feet, affording an excellent means of storing water during the wet months, to be available during the dry seasons, and amply sufficient to sustain a minimum flow of 150 cubic feet per second.

With an effective fall of 200 feet a total of 2,400 net horse-power can be relied upon at all times, this being more than will be required to meet the demands for a number of years.

At the present time the creek supplies the city of Whatcom with water, and is capable of furnishing a total of 25,000,000 gallons per day.

Various propositions for the development of this power have been made from time to time. Perhaps the simplest scheme would be to develop the power nearest the city first, which would furnish about 1,200 horse-power, and later, when a greater demand for power will exist, develop the rest of the falls.

NOOKSACK FALLS.

The Bellingham Bay & Eastern Railway, operating a steam railroad in the northwestern part of the state, has undertaken to develop the water-power of the falls of the Nooksack river. The falls are situated fifty-two miles, by rail, from the city of Whatcom, and fifteen miles beyond the present terminus of the road. Active work on the construction of a large power station has already begun. The power-house is to be located 1,500 feet below the falls, whose vertical height is 103 feet. The intake will be about 250 feet above the falls, and a large tunnel is being excavated. By so locating the power station an effective head of water of 179 feet is obtained; this with the amount of water being capable of developing a minimum of 10,000 horse-power. On account of the difficulty of handling material, three steel pipes, each thirty inches in diameter, will be run to the power-house instead of one large one; this will also permit the operation of a part of the plant as soon as the machinery is installed. All the power will be converted into electric energy. The transmission line is planned along the right-of-way of the railroad. The company expects to supply the Great Excelsoir Mining Company, located close by, as well as the rest of the mining properties in the vicinity, with power. An electric railway into the mining districts is also to be operated from the falls, and ultimately a line supplying the Bellingham bay cities with light and power, is to be constructed.

TUMWATER FALLS, NEAR OLYMPIA.

About two miles south of Olympia, at what is known as Tumwater, are a series of three falls in the Deschutes river, aggregating a total fall of about 78 feet. The flow of water is somewhat variable, being about eight times greater during February and March than in July and August. There is at present a power station built at that place, utilizing the water of the upper falls, or an effective height of 46 feet. The construction of the plant is in brief as follows: From a retaining wall a flume, 10 feet square on the inside, has been built toward the lower fall. A tap, eight feet square, is taken from this to the power house and operates two pair of 25-inch and one pair of 17-inch turbine wheels, capable of developing about 1,200 horse power. During the dry months, however, the supply of water is not sufficient to operate all of these at full load. The present output of the plant averages about 800 horse power, which is used for lighting, power and street railway purposes.

In order to obtain the most out of the available water power it should be developed all at one fall and in one power house. By building a storage pond at the upper fall, and with proper allowance for low tide, an effective fall of 48 feet could be obtained. This will require a good deal of blasting of rock, especially at the lower falls, inasmuch as the river bed is composed entirely of solid rock. The table below shows the discharge of the falls and horse power obtained at 84 feet fall.

MONTH.	*Cu. ft. per sec.*	*H. P. at 84 ft.*
January	781	5,580
February	1,060	7,550
March	1,040	7,400
April	692	4,900
May	416	3,000
June	251	1,800
July	120	860
August	104	740
September	142	1,010
October	357	2,540
November	634	4,500
December	925	6,600

During the three driest months the available power would be somewhat below 1,000 horse power, but for the rest of the year it is safe to assume it at 3,000. Inasmuch as the lightest load would fall upon the plant during the summer months, the capacity of the plant might be rated at 3,000 for the entire year by the addition of a small supplementary steam plant.

The present plant is the only one operated in that vicinity, and has, up to this time, been able to meet all demands for electrical power.

CARBON RIVER AND EVANS CREEK, FAIRFAX.

In the vicinity of Fairfax, Pierce county, are situated several mines utilizing water power to a great extent, and in a way which might serve as a model to many mines in similar positions.

The Montezuma Mining Company operates several mines and a lumber mill about two miles from Fairfax and utilizes the water power of Evans creek, a small mountain stream, to its full capacity. The water is brought to the entrance of the mines in a wooden flume 3x4 feet, where it has a vertical effective fall of 89 feet through a penstock, operating a 350 horse-power turbine. A two-horse-power blower is also operated from this fall. The power developed is used for the operation of the saw-mill, a small machine-shop and the machinery in the coal-bunkers. A 15-horse-power dynamo furnishes electric light for the mine and shops. An air compressor, used to furnish power for the mine drills, is driven by the same turbine. The water, after it has left the turbine, is diverted into two shallow flumes, used for coal and lumber respectively. The latter are flumed from the bunkers and mill for a distance of three-fourths of a mile, where they can be loaded on railroad cars. The plant has been in operation for some time and been running very satisfactorily; it being unique in the way that the full amount of power being utilized for the operation of the most varied kinds of machinery, electric lighting, saw-mill and coal handling and compressed air machinery, all being run from one small creek.

The Western American Mining Company, very near Fairfax, has partially utilized the water-power of the Carbon river. Owing to the absence of any appreciable fall in this river a flume 8x4 feet has been built, extending up along the river for about one mile. A penstock, giving a vertical fall of 47 feet, is built above a 300-horse-power turbine, operating a 200 kilo-watt generator. This generator furnishes power for ventilating the mine, operating the electric locomotives, the coal bunkers, coal-handling machinery and machine-shop, and also lights the town of Fairfax and the mines proper.

An additional installation of a 250-horse-power turbine will be made shortly, although at present the water supply at its lowest stage is not quite sufficient to operate both turbines at one time.

PART VI.

BIBLIOGRAPHY OF THE LITERATURE REFERRING TO THE GEOLOGY OF WASHINGTON.

BY

RALPH ARNOLD.

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[NOTE.—In addition to the following articles, references to the geology of Washington may be found in the reports of the United States Geological Survey relating to mineral resources and economic geology, and also in the reports of the Canadian Geological Survey.]

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