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HENRY LANDES, STATE GEOLOGIST.

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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.

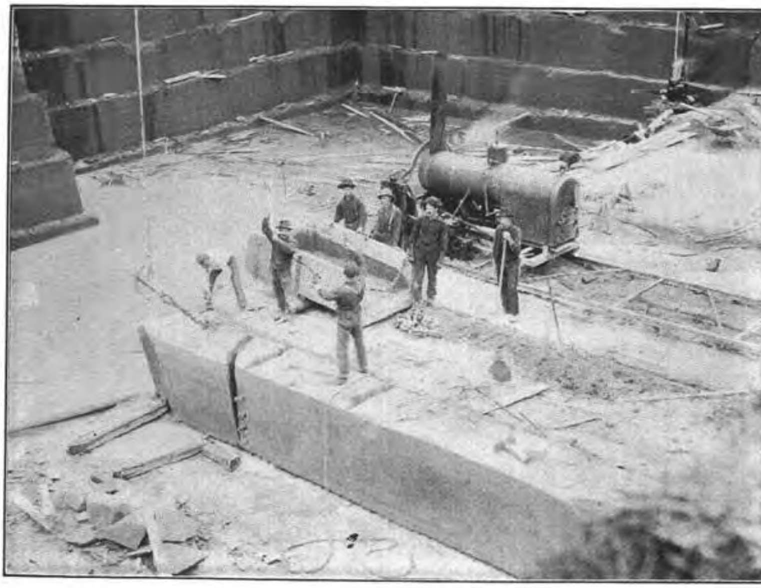
Farther up the Snake than the locality last mentioned, near the mouth of the Grand Ronde river, Mr. Moore has another granite quarry, but which is not as accessible as the first one. The stone is a dark gray hornblende-biotite granite, rather fine grained. It takes a beautiful polish and has been used 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.

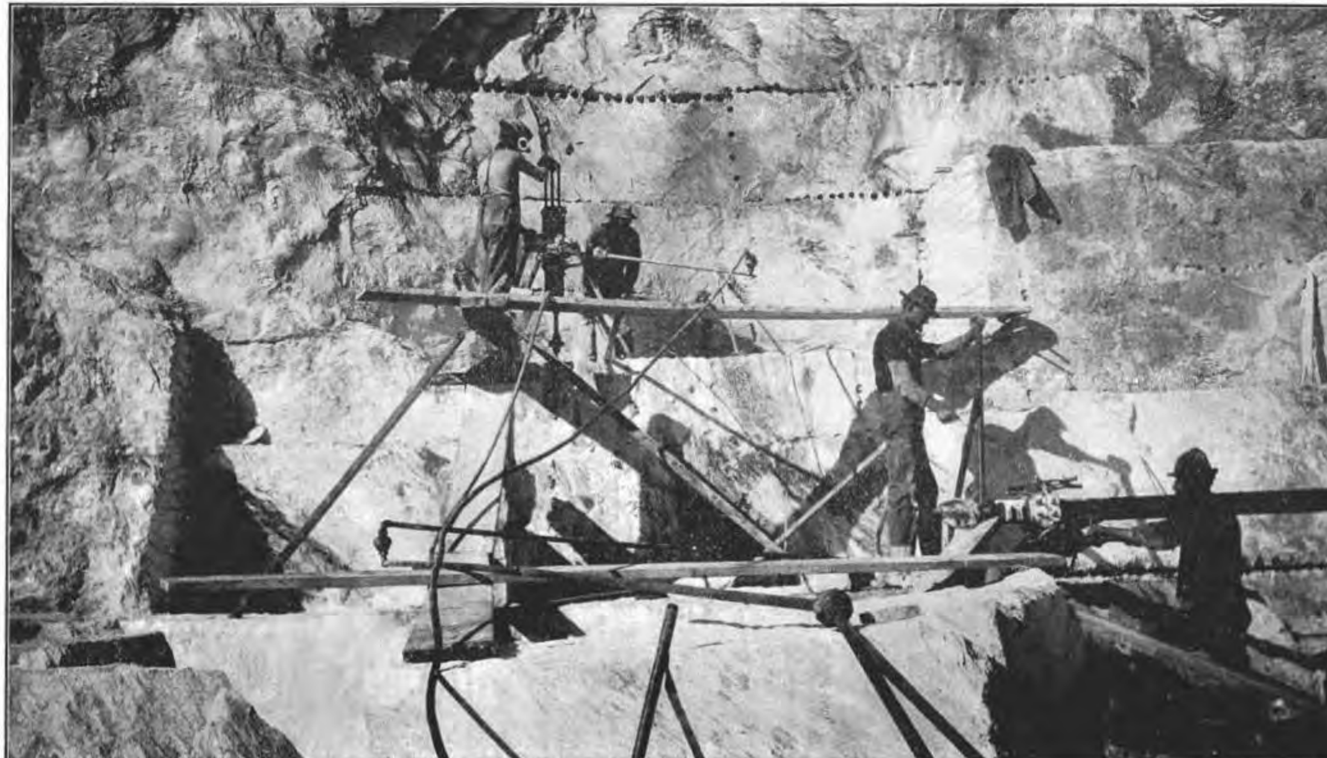
Wilkeson.

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.

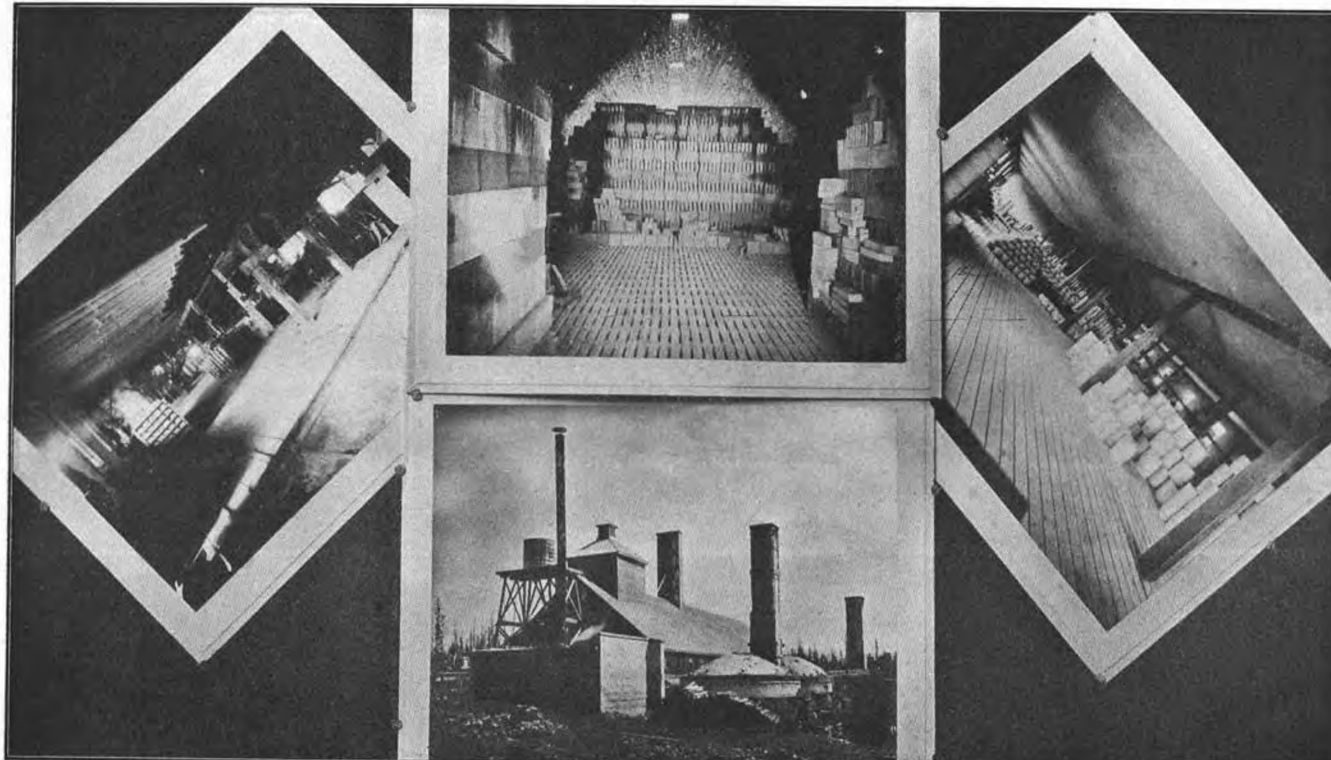
Dry pressed brick is heated slowly and burned carefully for ten or twelve days, the time varying with the character of the clay and the amount of heat it requires. Both pipe and brick attain a white heat, from which the brick will not cool in less than four days, on account of absoption due to thickness. 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.

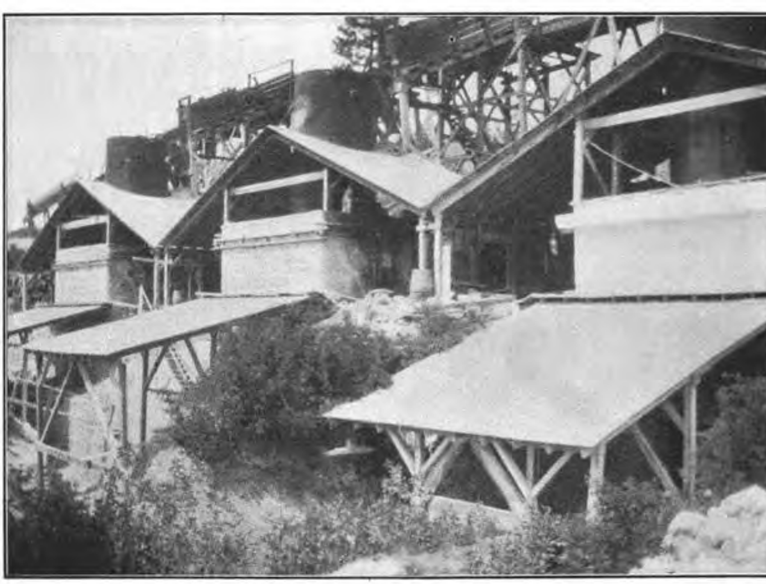
The equipment consists of four continuous kilns, capacity 500 barrels daily, track, cars, and other necessary machinery; buildings, consisting of store houses, office, residences, etc.

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	.318	.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.