CHAPTER VII.

CEMENT MATERIALS OF EASTERN WASHINGTON.

The geology of eastern Washington is such that only in a few localities will Portland cement ever be manufactured. The southern part of the state, east of the Cascade mountains, is a vast area of basalt and only in a few places are other kinds of rocks known to occur, and in but one place in this area has limestone been found. Clays are abundant and some of them could be used in the manufacture of Portland cement. The limestones of eastern Washington, so far as known now, occur in Asotin, Stevens, Ferry and Okanogan counties.

ASOTIN COUNTY.

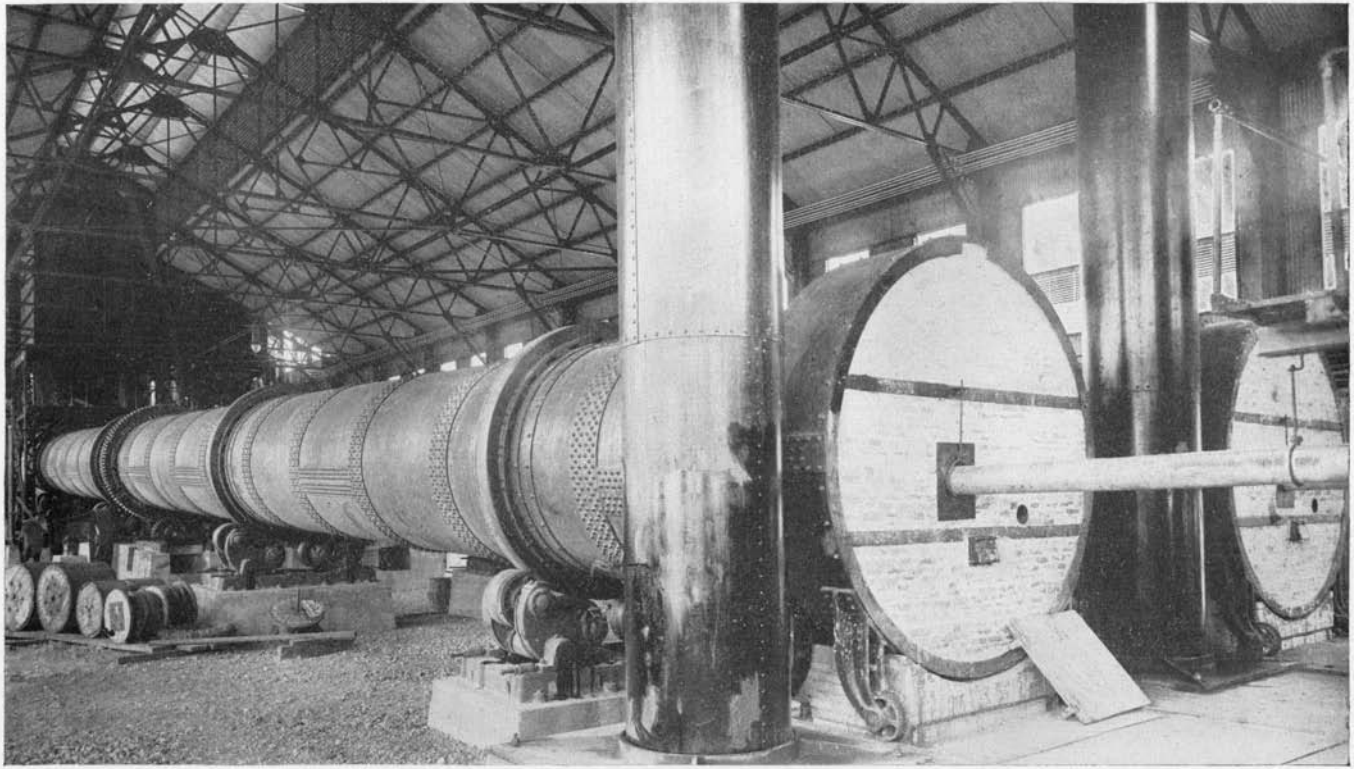
This county is situated in the extreme southeastern corner of the state. The Snake river flows in a deep gorge along the entire eastern side of it, and along about half of the northern side.

TOPOGRAPHY.

The surface of the county is very uneven and ranges from about 750 to more than 4,000 feet above sea level. The principal streams which drain the surface of the county are the Grande Ronde river and Asotin creek, both of which empty into the Snake river. In addition to these, there are a number of other smaller streams such as George, Mill, and Ten Mile creeks. A considerable part of the surface of the county is a comparatively level plateau, some distance above sea level and in which the main streams have cut very deep, steep sided gorges. In the southwestern part of the county, which includes a part of the Blue Mountains, the highest altitude is reached.

GEOLOGY.

Asotin county lies wholly within the basaltic area and in only a few places within the county are rocks, other than basalts, exposed. In places, however, in the deep canyon along the Snake river, older formations are shown. The first exposure above Asotin of these older rocks is at what is known as Buffalo Rock,



Rotary Kilns, 8½ x 160 feet in size, in the Plant of the International Portland Cement Company, near Spokane.

which is about fifteen miles above the town. Here the metamorphic rocks which formed the surface of this part of Washington before the vast inundations of molten lava took place, have been exposed to a depth of at least 2,000 feet by the Snake river cutting down into them for this distance. These rocks are mostly schists and are largely of a greenish color.

Russell in his description of the schists, has the following to say in regard to them:

"The rocks which cause these important changes in the character of the canyon are mostly greenish, spotted schists, and are evidently of sedimentary origin, as well-rounded pebbles and angular masses of rock may still be recognized in them. Samples may be collected showing a transition from conglomerate, in which the pebbles are still prominent, through schistose rock containing flattened and elongated pebbles, to greenish schist with spots and blotches due to altered pebbles, and from these, again, to fine even-grained, silky schists of uniform color. Near the southern end of the exposure, there are rocks of plutonic origin, which appear breaking through the schists, but as a similar rock occurs as pebbles in the schists, it is evident that at least some of the intrusives were formed before the material since metamorphosed was deposited."*

Just above the mouth of the Grande Ronde river, these metamorphic rocks appear again, above the surface of the river and form a large part of the walls of the Snake river canyon. From here they extend up the river for a number of miles. The appearance here is very similar to that at Buffalo rock. The basalt which is practically horizontal abuts against cliffs of schists and shows no change at the contact. At this place, in addition to the schists, limestones also occur, and the area just above the mouth of Grande Ronde river on the Washington side of the Snake river, has been designated Lime hill, while on the Idaho side it is known as Lime point.

LIME HILL CEMENT DEPOSITS.

Lime hill is about twenty-five miles above Lewiston, Idaho, on the Washington side of the Snake river. It has no very satis-

*Water-Supply and Irrigation Paper No. 4, U. S. Geol. Survey, pp. 31-32.

factory transportation facilities at present (June, 1913). Boats ascend the Snake this far occasionally, but no regular trips are made and the nearest railroad point is Lewiston. There is, how-

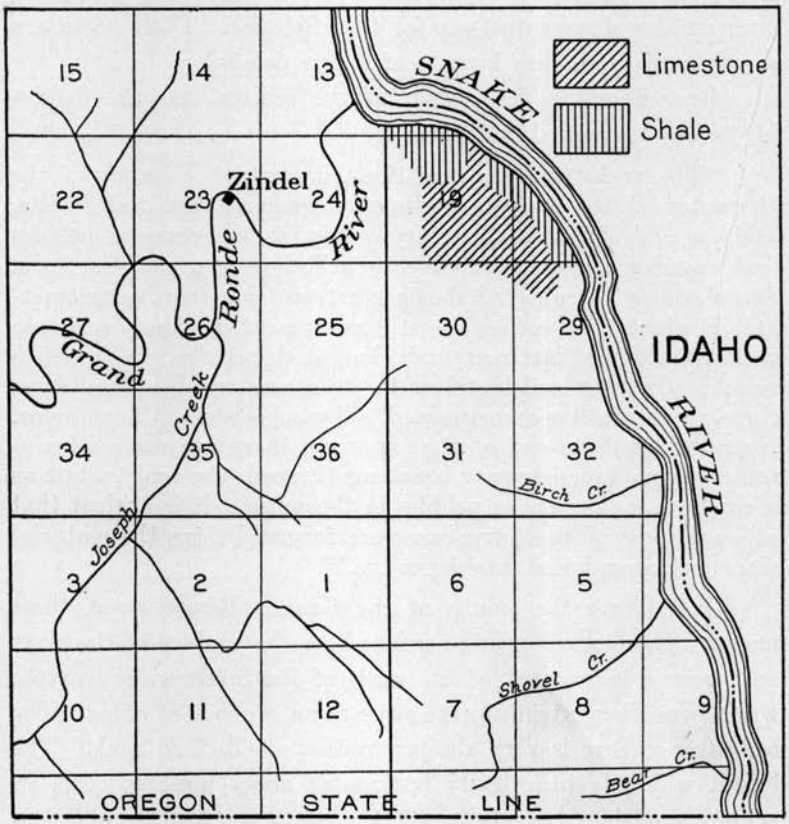


FIG. 1. Limestone and Shale deposits along the Snake River, near Zindel, Asotin County.

ever, a very good wagon road from Asotin to Lime point along the Snake river.

Field Examination.—The old metamorphic rocks which are found here are limestones, shales, and slates. These are of sedimentary origin and in places show distinct stratification. The limestone occurs in a high rounded hill which has an altitude of about 2,600 feet. The schists which occur here and on which

the limestone appears to lie, are of various colors, the reds and greens being very common. These schists vary also in texture, in some cases being very fine grained while in others they are quite coarse. Running through these schists are many small veins in some cases of quartz, and in others of calcite.

Shales are also found in places in this locality but the indications are that they have been formed by the weathering of a very siliceous limestone which had been subjected to extreme pressure and had become more or less schistose. These, however, do not cover very large areas, and probably do not extend very far below the surface. One of the best exposures of this shaley material is at a point where a little development work has been done in the N½ of the SE¼ of the SW¼ of section 19, township 7 north, range 47 east, of the Willamette Meridian. At this point there appears to be about 50 feet in thickness of this material, steeply inclined, with limestone on either side of it.

The limestone deposits which occur here are very extensive, as they cover a large area and are very thick. The limestone does not show any very marked stratification at this point. The strike of the beds is west of north a few degrees, and the dip is to the north. The limestone lies above the schists and appears conformable with them. Contacts were not easily found, however, and it is not possible to say positively in regard to this point. No fossils were found in the deposits and their age is not known. Russell, nevertheless, reports fossils from here. He has the following to say in regard to the metamorphic rocks which occur between the mouth of the Grande Ronde river and Wild Goose creek:*

"The rocks are plainly of sedimentary origin, as their stratification is prominent. They have a thickness of several thousand feet. The strata in the northern part of the section are inclined northward at an angle of from 40° to 45°, and in places are nearly vertical. A great dome of ancient rocks has been cut through. The upper layers of the dome are thin-bedded siliceous limestone containing indefinite fossils. Beneath

*Water-Supply and Irrigation Paper No. 4, U. S. Geological Survey, p. 33.

this are thick layers of thinly laminated, granular limestone, containing some silt and organic matter, which appear in conspicuous white ledges. This rests on schists that show a diversity of colors, varying from green to red, and are frenquently fine and silky in appearance. Marked contrasts are apparent in the schists, some layers being schistose, conglomerates, or breccias, while others resemble the finest roofing slate. The schist has great thickness, and is believed to rest on granite. The lower contact of the schist was not seen, but granite occurs abundantly in the pebbles along Snake river, and is reported by miners to come to the surface a short distance above Wild Goose creek. The topography in that region bears out this statement."

Mr. J. S. Diller* reports that thin sections of this limestone examined under the microscope "do not show fossil forms nearly so distinctly as the weathered surfaces. The specimen was shown to Mr. G. H. Girty, and he agrees with me, not only that the fossils are crinoids, but that one of them has a pentagonal stem. Crinoids with stems of this sort are not definitely known to be older than the Permain, and it is probable that this one is considerably later. The specimens examined look very much like the Jurassic limestone of California, in which fossils are abundant."

Laboratory Examination.—The shale which occurs on Lime hill varies somewhat in color and ranges from a dark to a light gray, and when finely pulverized is very light, almost white in color. It separates readily into very thin layers and has a very shaley structure.

The following analysis shows the chemical composition of this shale at a point on the western side of the hill, where a small opening had been made and the shale well exposed:

ANALYSIS OF SHALE FROM LIME HILL, ASOTIN COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	26.28
Alumina (Al_2O_3)	15.32
Iron (Fe_2O_3)	1.57
Lime (CaO)	28.72
Magnesia (MgO)	trace
Loss on ignition	27.17
Total	99.06
Calcium carbonate ($CaCO_3$)	51.28

*Water-Supply and Irrigation Paper No. 4, U. S. Geological Survey, p. 33.

The above analysis shows this to be a very calcareous shale, with a very small amount of iron and practically no magnesia. The amount of alumina is fairly high, but the silica is low, the ratio between these being one of alumina to only 1.85 of silica. This would make it necessary to have some more siliceous material to add to the limestones which occur here, in order to make Portland cement.

The schists which occur here have not been analyzed, but they are undoubtedly much higher in silica and might perhaps be a source from which this might be derived.

Just across the Snake river, on the Idaho side, there occurs a body of almost pure white clayey material which carries a high percentage of silica. This material occurs in the contact between the limestone and the basalt. In places at least this clay has a thickness of about ten feet and it can be traced across the country for at least one-half a mile. This clay was not found on the Washington side of Snake river, but still it may occur, as no good contact between the basalt and limestone was found.

The following analysis shows the chemical composition of this material:

ANALYSIS OF CLAY FROM LIME POINT, IDAHO.
H. C. JOHANSEN, Analyst.

Silica (SiO_2)	68.88
Alumina (Al_2O_3) / Iron (Fe_2O_3)	17.04
Lime (CaO)	1.11
Magnesia (MgO)	0.40

The above partial analysis shows the percentage of silica this clay carries. While the percentage of iron was not determined, it is very small, as the clay is almost pure white.

The limestone which occurs here varies but little in color, the most of it being dark gray. When pulverized it appears much lighter in color and in fact it is almost white. It is fine grained, not very hard and pulverizes very easily. It contains minute glistening particles disseminated through it which are recognizable with the naked eye and very easily distinguished by the aid of a hand lens. Its color is due to impurities which are probably largely carbonaceous, for when highly heated the dark color disappears and it is almost pure white. In dilute

hydorchloric acid it effervesces very freely and after the corbonate of lime is completely dissolved there remains a small amount of a very fine dark sediment.

The following analyses show the chemical composition of this limestone:

ANALYSES OF LIMESTONE FROM LIME HILL, ASOTIN COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.	III.	IV.
Silica (SiO_2)	9.82	5.98	6.10	5.48
Alumina (Al_2O_3) } Iron (Fe_2O_3) }	2.24	2.04	2.16	3.50
Lime (CaO)	48.33	51.07	50.06	49.99
Magnesia (MgO)	0.79	0.78	0.68	0.65
Loss on ignition	38.18	39.93	39.60	40.20
Total	99.36	99.80	98.60	99.82
Calcium carbonate ($CaCO_3$)	86.30	91.20	89.40	89.25

I. West side of hill, near contact of basalt and limestone.
II. Partially decomposed limestone.
III. From near summit of hill.
IV. Weathered limestone from west side of hill.

The above analyses show this limestone to be practically free from magnesia. The amount of lime is not especially high, yet it is not so low but what the stone can be used for Portland cement. All of these samples were taken from the surface and, while they undoubtedly show fairly well the composition of the surface material, the limestone some distance below the surface where it has not been so much affected by weathering agencies would carry a higher percentage of lime.

The percentage of silica, as shown by the above analyses, is higher than usually occurs in the best grades of limestone, but in this particular case this would be an advantage rather than a detriment, as the silica is the substance most needed in this locality. The amount of iron was not determined in any of these samples, but it is undoubtedly small. The ratio between the silica and alumina is not far from that in a Portland cement mixture.

Across the Snake river, on the Idaho side, the same deposit of shales and limestones occur. The shales are much more extensive here than they are on the Washington side and are more

weathered. The limestones are very similar to those on the Washington side, except that they show a higher percentage of lime. This is probably due to the fact, at least to a certain extent, that the samples from the Idaho side of the river have been weathered less than those from the Washington side.

The following analyses show the chemical composition of this limestone:

ANALYSES OF LIMESTONE FROM LIME POINT, IDAHO.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	0.66	0.12
Alumina (Al_2O_3) } Iron (Fe_2O_3) {	0.54	0.20
Lime (CaO)	54.91	55.71
Magnesia (MgO)	0.23	0.25
Calcium carbonate ($CaCO_3$)	98.05	99.48
Magnesium carbonate ($MgCO_3$)	0.48	0.52
Total	99.73	100.32

I. Elton Fulmer, Professor of Chemistry, Washington State College, and State Chemist, Analyst.
II. H. C. Johansen, Analyst.

The above analyses show this to be an exceptionally pure limestone.

The following analyses show the chemical composition of some of the shales from the same locality:

ANALYSES OF SHALES FROM LIME POINT, IDAHO.

CONSTITUENTS	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Silica (SiO_2)	37.28	18.42	37.20	41.34	23.96	35.74	17.74	26.87
Alumina (Al_2O_3) } Iron (Fe_2O_3) {	12.88	8.29	11.44	15.63	9.16	13.65	9.08	11.84
Lime (CaO)	25.76	36.46	25.80	20.06	35.67	25.07	39.13	31.75
Magnesia (MgO)	1.42	2.85	2.54	4.04	1.81	3.47	2.16	2.14

I.-II. Elton Fulmer, Professor of Chemistry, Washington State College, and State Chemist, Analyst.
III.-VIII. H. C. Johansen, Analyst.

The samples from which the above analyses were made were taken from various parts of the deposits, and are thought to be fairly representative of them. They are all very calcareous with small amounts of magnesia. The amount of silica is a little

small in most of these samples, for the percentage of iron and alumina. Judging from the color only, nearly all of what is given above as iron and alumina is alumina.

STEVENS COUNTY.

Stevens county is situated in the northeastern part of the state, and is one of the largest counties in it.

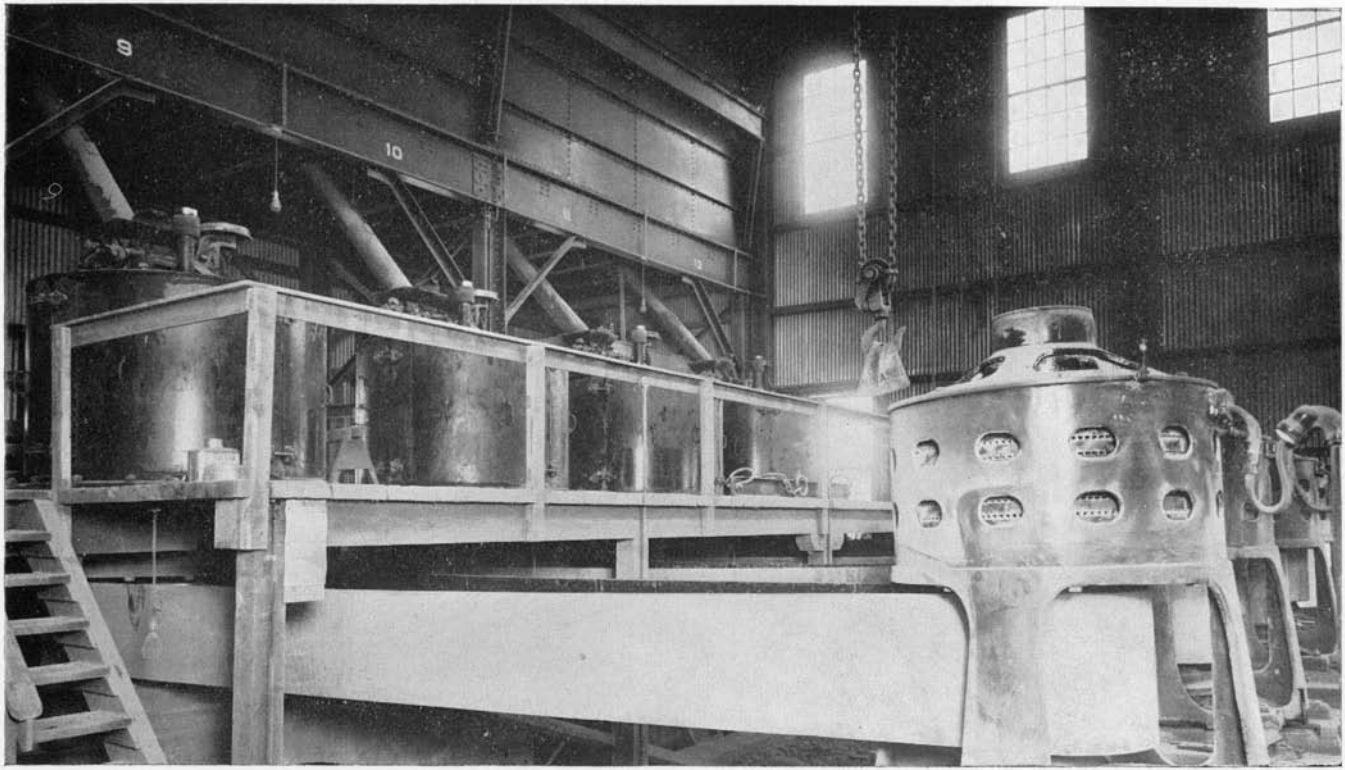
TOPOGRAPHY.

The surface features consist largely of parallel mountain ranges extending north and south almost across the county. Between these mountain ranges are two long comparatively narrow valleys through which flow two of the principal streams, the Columbia and the Colville rivers, that aid in draining the surface of the county. The extreme southern part of the county is drained by the Spokane and Little Spokane rivers and their tributaries. The general altitude of the southern part of the county, as shown by maps of the Northern Transcontinental Survey, is about 2,600 feet above sea level.

The mountains between the Columbia and the Colville river in places reach an altitude of more than 6,000 feet above sea level, while those along the eastern side of the county have an average altitude of about 4,800 to 5,500, while the highest point, Calispell peak, has an altitude of 6,905 feet above sea level.

GEOLOGY.

The rocks throughout Stevens county are very largely metamorphic and consist of slates, marble, quartzite, schist, and limestones and rocks of this general character. In places, however, large areas of plutonic rocks, such as granites, which show but little the effects of metamorphic action, do occur. In some localities highly metamorphosed limestones or marbles are found in contact with the granite. The limestones show stratification in but very few places, the metamorphism having been great enough in most instances to destroy all evidences of it. The disturbances which have taken place have broken the deposits badly in most places so that they are filled with seams and cracks.



Pulverizers for Grinding Clinker in the Plant of the International Portland Cement Company, near Spokane.

Limestones are quite general throughout Stevens county, the southern limit, in a general way, being about 48° north latitude. At Valley Brook, four miles north, limestones occur and for several years were quarried and burned for lime. From here to the northern boundary of the state they are very common. They occur in more or less isolated masses, sometimes covering large areas and in others only compartively small ones. They occur on either side of the Colville Valley for its entire length. In most cases they are found back in the mountains from 10 to 20 miles from the valley. North of the Colville valley they occur along the Columbia river and from Evans to the northern boundary they are very common.

The limestones throughout the county have every evidence of being the remnant of what was at one time a large deposit covering in all probability large areas in the northern part of eastern Washington. When this part of the state became a land area erosion began acting on it and in the course of time removed the larger part of this limestone deposit and what we have now are simply comparatively small masses that on account of the peculiar conditions or physical properties of the limestone have not been entirely removed.

COLVILLE VALLEY.

The Colville valley extends from near the southern central part of Stevens county to the Columbia river, at Kettle Falls, and is drained by the stream of the same name. In the foot hills and mountains on either side of this valley, especially the northern part of it, limestone deposits are very common. In many cases these have undergone very great changes, and have been metamorphosed to form marbles. Many chemical analyses of these marbles have been made and are published in Vol. II of the Washington Geological Survey.* It also includes detailed descriptions of many of the deposits. The analyses show many of the deposits to have so much magnesia that they are of no value as materials from which to manufacture Portland cement.

*Shedd, Building and Ornamental Stones of Washington, pp. 87-105, 109-131, 142.

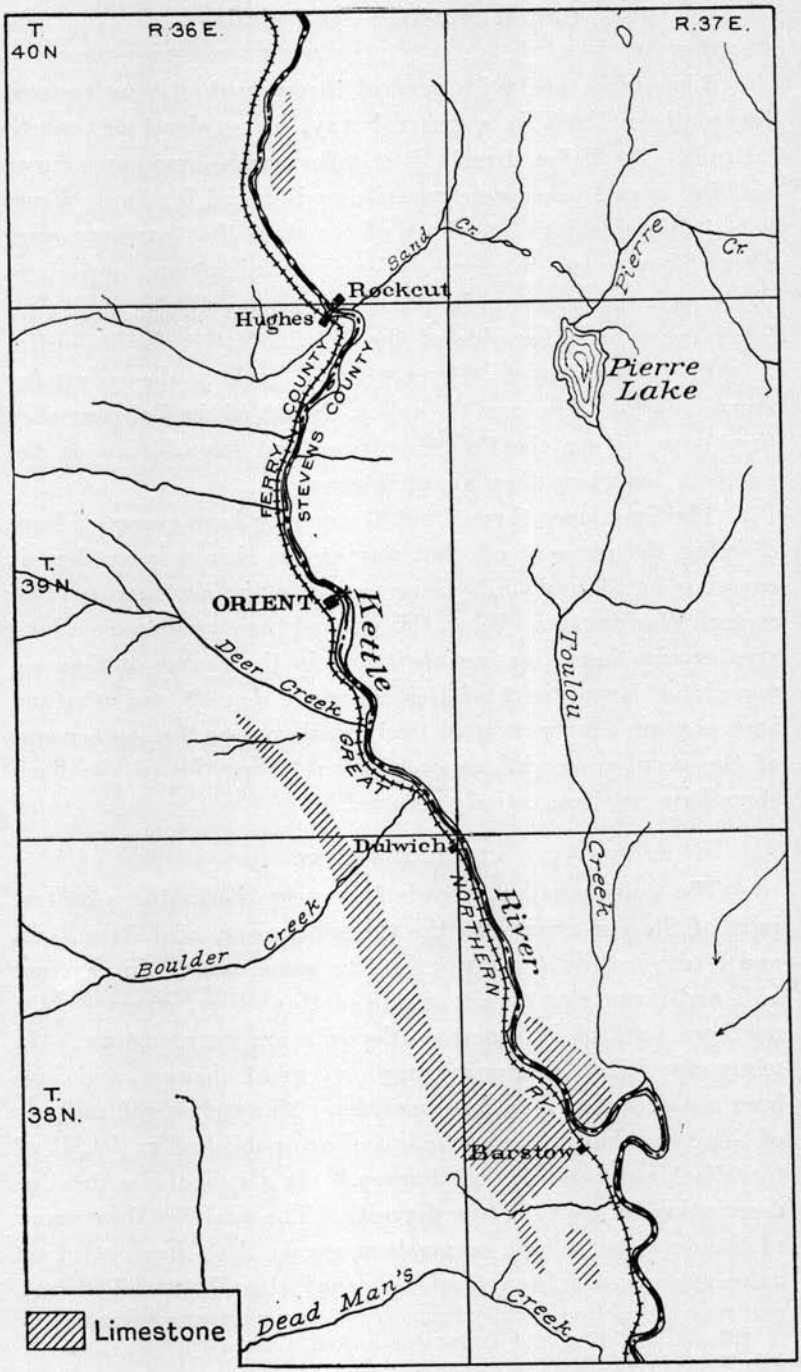


FIG. 2. Limestone deposits along the Kettle River, between Ferry and Stevens counties.

Shales are found at many places in the foothills, while clays are more or less widely distributed throughout the valley.

SPRINGDALE.

To the north and east of Springdale, in sections 22, 23, 24, 25, 26, and 27, township 30 north, range 40 east, limestones occur which have been used more or less at different times in the manufacture of lime. The limestone is found in contact with basalt in places, especially on the north and on the south. This limestone is light gray in color and finely crystalline. When pulverized and treated with dilute hydrochloric acid it effervesces rapidly and is completely dissolved. Samples from various places over this area appear to show more or less variation in composition, but in general it has considerable magnesia. For a number of years, the Washington Brick, Lime and Manufacturing Company had a large plant for the burning of lime located at Springdale and obtained limestone for it from this deposit. In two other places in this area lime kilns have been located and some of this limestone burned.

This area represents the only locality in eastern Washington so far as the writer is aware where fossils have been found in the limestones. Those found here are poorly preserved and have not been identified yet. They appear, however, to be corals. They are not plentiful and give very little hope of proving much as regards the age of the deposits in which they occur.

VALLEY.

Jump Off Joe Lake.

This is a small lake situated about three miles south and one and a half miles east of the town of Valley. Limestones occur on the west and south sides of the lake and are in section 36, township 31 north, range 40 east, and sections 1 and 12, township 30 north, range 40 east. Lime is being burned from this deposit, one small kiln being operated for a part of the year. The deposits cover a considerable area and appear to be fairly thick. They have a very uniform appearance through-

out, both in color and in texture, but show no signs of stratification.

Laboratory Examination.—This limestone is very fine grained, the largest crystals that occur in it being hardly distinguishable with the naked eye. It is dark gray in color, and has a flinty appearance. When pulverized, this limestone is light gray in color, effervesces rapidly when treated with dilute acids, and dissolves with the exception of a very small, almost white, gritty residue.

Two samples from different parts of this deposit were analyzed, with the following results:

ANALYSES OF LIMESTONE FROM JUMP OFF JOE LAKE, STEVENS COUNTY.

A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	1.58	1.47
Alumina and Iron (Al_2O_3, Fe_2O_3)	1.78	0.65
Lime (CaO)	54.02	54.12
Magnesia (MgO)	1.23	none
Loss on ignition	41.38	43.50
Total	99.99	99.74
Calcium carbonate ($CaCO_3$)	96.46	96.64

I. S. E.½, Sec. 36, T. 31 N., R. 40 E.
II. S. W. ¼, Sec. 1, T. 30 N., R. 40 E.

The above analyses show these two samples to be almost exactly the same in composition and to be high grade limestone, well suited for the burning of lime or for use in the manufacture of Portland cement.

Some other limestone deposits also occur in this locality, but they are small and no analyses were made of samples from them.

Limestone deposits occur in various places west and northwest of Valley. These occur in isolated patches sometimes covering very small areas only, while in others they extend over several square miles. In some places they are very coarse grained,

and in others very fine grained. In color there is much variation also, white, blue, gray, and pink predominating.

Field Examination.—In sections 1 and 12, township 31 north, range 39 east, and in sections 6 and 7, township 31 north, range 40 east, are large deposits of limestone with a general north and south strike and a dip to the east. They lie on a dark green igneous rock which occurs to the west of them, and dip away from it.

In sections 30 and 31, township 32 north, range 40 east, and sections 25 and 36, township 32 north, range 39 east, are limestone deposits that have a north and south strike and dip to the west. These limestones vary in color somewhat, in places being a dirty white, while in others they are light gray. In some places light and dark layers alternate, giving a somewhat banded appearance to this stone.

Farther west, in sections 8 and 9, township 31 north, range 39 east, are other limestone deposits. In Greenway Mountain, which is composed largely of slates and limestones, the strike is north about 10° east, and the dip to the north at an angle of about 45°. The slate and limestone appear to be comformable with the slate above the limestone. The limestone is very coarsely crystalline and almost black in color.

Other deposits are found in section 19, township 31 north, range 39 east, and in sections 24 and 25, township 31 north, range 38 east. Pink is a very common color in these deposits. They are coarsely crystalline and very hard. Slates having a light gray color are also very common in this locality.

Laboratory Examination.—A number of samples have been examined from these various deposits and it is found that they are very similar in their general characters. They dissolve but slowly in cold dilute acids, are all rather coarsely crystalline, and are harder than most limestones.

The following analyses show the chemical composition of some of these deposits:

ANALYSES OF LIMESTONES FROM WEST OF VALLEY, STEVENS COUNTY.[1]

CONSTITUENTS.	I.	II.	III.	IV.
Silica (SiO_2)	6.48	18.18	5.79	0.89
Alumina (Al_2O_3)	4.20	0.44	0.43	none
Ferric iron (Fe_2O_3)		0.45	0.85	none
Ferrous iron (FeO)		1.17	none	0.58
Lime (CaO)	2.52	24.74	1.69	none
Magnesia (MgO)	41.53	16.10	42.07	45.76
Carbon dioxide (CO_2)	.....	38.18	47.23	49.24
Water above 110° and water at 110° (H_2O)	.....	0.05	.....	.....
Undetermined substances	.....	0.69	1.94	3.53
Loss on ignition	43.60	.....	.....	.....
Total	98.33	100.00	100.00	100.00

I. Light gray in color. Secs. 30 and 31, T. 32 N., R. 40 E. A. A. Hammer, Analyst.

II. Pinkish in color. Secs. 1 and 12, T. 31 N., R. 39 E., and Secs. 6 and 7, T. 31 N., R. 40 E. R. W. Thatcher, Analyst.

III. Dark, coarsely crystalline. Secs. 8 and 9, T. 31 N., R. 39 E. R. W. Thatcher, Analyst.

IV. Pink, coarsely crystalline. Sec. 19, T. 31 N., R. 39 E., and Secs. 24 and 25, T. 31 N., R. 38 E. R. W. Thatcher, Analyst.

[1]II.-IV. Washington Geological Survey, Vol. II, pp. 91, 98, 102.

The above analyses show a very high percentage of magnesia in all of these samples and this makes them valueless as materials from which to manufacture Portland cement.

Shales are very common in many places in this part of Washington, but no samples of them have been analyzed for this report.

About two miles east of Valley, in the NW1/4 of section 20, township 31 north, range 41 east, is a body of almost pure white clay. But little development work has been done on the deposits and it is not possible to say definitely how large a body there is of this clay.

A chemical analysis was made of it with the following results:

ANALYSIS OF CLAY FROM VALLEY, STEVENS COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	69.12
Alumina (Al_2O_3)	23.40
Iron (Fe_2O_3)	0.96
Lime (CaO)	trace
Magnesia (MgO)	0.92
Potash (K_2O)	0.17
Soda (Na_2O)	0.15
Loss on ignition	4.92
Total	99.64
Total fluxes	2.20

The above analysis shows a very good ratio between the silica and alumina. The amount of iron is so small that the clay, when burned, should be very light, almost white in color, but the total amount of the fluxing substances is so small that this clay would require a high temperature to fuse it.

Shales occur in the same locality with the clay. They vary much in color, some of them being purplish, while others are a very light gray. They all have a very rough, harsh feel and are very fine grained. Where unweathered they are quite hard. No development work has been done on these deposits.

The following analysis shows the composition of these shales:

ANALYSIS OF SHALE FROM VALLEY, STEVENS COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	28.36
Alumina (Al_2O_3)	2.29
Iron (Fe_2O_3)	5.39
Lime (CaO)	18.56
Magnesia (MgO)	6.01
Loss on ignition	32.41
Total	98.41

The above analysis shows a very small percentage of alumina for the amount of silica present in these shales. They carry a high percentage of lime and magnesia and in all probability considerable free silica as sand.

Shales are found closely associated with the limestones around Jump Off Joe lake, especially on the west and, while they were not analyzed, it is quite probable that in places, at least, they may have the composition desired for Portland cement material. These shales cover a very large area in this locality and would be inexhaustible. On the south both shales and the limestones are in contact with basalt.

CHEWELAH.

Chewelah is six miles almost due north of Valley, on the Spokane Falls and Northern railway, and is one of the most important towns in the Colville valley. Limestones, shales and clays are found in this locality.

The limestones are mostly east of Chewelah, and occur in a narrow belt, with a general north and south extent, of a little

more than seven miles. They occur in sections 5, 6, 7, 13, 19, 30, 31, and 32, township 32 north, range 41 east, sections 28, 29, 32, and 33, township 33 north, range 41 east, and sections 1, 12 and 13, township 32 north, range 40 east. This stone varies much in color and ranges from pure white to very dark gray. The general direction of the strike is north and south with a dip to the west. The limestone varies much in appearance and purity in various parts of this area and in fact in places other formations appear to predominate. The Blue Star mine has a tunnel a little more than 200 feet deep, all the distance being in this limestone. In some places the limestone is in contact with shale, in others with quartzite, while in still others it lies on granite.

Laboratory Examination.—The limestone from this locality is fine grained and harder than most limestone. When pulverized the dark gray samples are very light gray in color and when treated with cold dilute hydrochloric acid effervesce only slowly, but are practically all dissolved in a short time. The samples of white limestone effervesce more rapidly when treated with cold dilute acids than the others do, but a much larger amount of undissolved material is left.

Thin sections of the white limestone, when viewed under the microscope, show it to be composed of a mass of grains that vary but little in size, the largest ones being about .5 of a mm. in diameter. Twinning is very common, the twin lamellae being almost parallel to the longer diagonal of cleavage rhombs. The sections are slightly clouded in most places, due to a very small amount of impurity in them. Minute grains of iron sulphide are quite common throughout the sections. Cleavage is well marked, many sharp cracks appearing in the sections.

The following analyses show the chemical composition of two samples from these deposits:

General View of the Plant of the Inland Portland Cement Company at Metaline Falls.

ANALYSES OF LIMESTONES FROM EAST OF CHEWELAH, STEVENS COUNTY.

A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	3.15	5.26
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.41	1.46
Lime (CaO)	31.55	32.56
Magnesia (MgO)	20.11	14.90
Loss on ignition	43.91	43.96
Total	99.13	98.14

I. Dark colored. Sec. 32, T. 32 N., R. 41 E.
II. White. Sec. 5, T. 32 N., R. 41 E.

The above analyses show these samples to be very similar in composition, even though the places from which they were taken are about five miles apart. They are thought to represent fairly well the composition of the limestones in this locality. They are low in lime and high in magnesia and judged by these analyses are of no value for Portland cement.

BLUE CREEK.

Limestones occur about one mile east of Blue creek, in section 32, township 33 north, range 40 east. This deposit, however, covers but a very small area and no samples of it were analyzed. It is surrounded on all sides by quartzite.

About two and one-half miles farther east and one mile north in sections 22, 23, 26 and 27, township 33 north, range 40 east, is another small deposit of limestone which, like the other, is surrounded by quartzite.

ADDY.

Limestone.

Large areas of limestone are found northwest of Addy. These begin just west of the town and extend back to the head waters of Stranger Creek, which are about eight miles distant. The deposits are not continuous for the whole distance but occur in three or four separate areas. One of the largest of these occurs in sections 3, 4, 9 and 10, township 33 north, range 39 east, and sections 29, 32 and 33, township 34 north, range 39 east. This deposit has a width of about one mile and a length of

a little more than three miles, and in places is exposed in perpendicular bluffs as much as 50 feet high.

The character of the limestone appears to be quite uniform over the whole of this area. It varies from almost white to dark gray in color and does not show very marked stratification. The general strike of the beds appears to be a little west of north with a dip to the south and west. The deposits occur in more or less rounded hills in general, which rise in places more than 100 feet above the stream valleys. Shales occur on the south and west sides of these limestones and appear to be conformable with them, while on the north and east they lie on granite and quartzite.

The section given below shows the relation of the granite, quartzite and limestone, beginning in the southwest corner of section 34, township 34 north, range 39 east, and extending south to Stranger Creek.

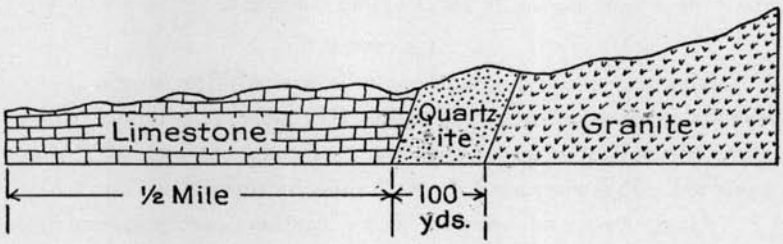


FIG. 3. Cross-section of formations near Stranger Creek, Stevens County.

Laboratory Examination.—This limestone is hard and very fine grained. When pulverized it is light gray in color and when treated with cold dilute hydrochloric acid, effervesces very slowly and is only partially dissolved.

The following analysis shows the chemical composition of the limestone from this deposit:

ANALYSIS OF LIMESTONE FROM NEAR ADDY, STEVENS COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	2.84
Alumina and Iron (Al_2O_3, Fe_2O_3)	1.31
Lime (CaO)	31.25
Magnesia (MgO)	19.12
Loss on ignition	43.89
Total	98.41

The sample from which the above analysis was made came from the SW¼ of the SW¼ of section 3, township 33 north, range 39 east. It shows the limestone in this part of the deposit, at least, to be low grade, carrying only 55.8 per cent. of calcium carbonate ($CaCO_3$) and a large amount of magnesia, in fact almost enough so that it would be considered a dolomite.

Shales.

Shales cover a large area to the south and west of the limestone deposits described above. These shales are thinly laminated and on the surface are broken into small pieces. As already stated, where they are in contract with the limestones, they appear to be conformable with them. The area examined is mainly in sections 19, 20, 29, 30, 31 and 32, township 34 north, range 39 east, and sections 13, 24 and 25, township 34 north, range 38 east.

Laboratory Examination.—This shale is very fine grained and not very hard. When pulverized it is light gray in color and when mixed with water is but little plastic. When treated with cold dilute acids there is a considerable amount of effervescence which indicates the presence of carbonates.

The following analysis shows the composition of this shale:

ANALYSIS OF SHALE FROM NEAR ADDY, STEVENS COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	54.41
Alumina (Al_2O_3)	16.83
Iron (Fe_2O_3)	3.21
Lime (CaO)	12.54
Magnesia (MgO)	trace
Loss on ignition	12.83
Total	99.82

Near section line between Secs. 19 and 30, T. 34 N., R. 39 E.

The above analysis shows that this shale is a little low in silica with about an average amount of alumina and iron. The ratio between the silica and the alumina and the iron, however, is not so low but what this shale might be used in the manufacture of Portland cement.

COLVILLE.

Colville, the county seat of Stevens county, and the largest town in it, is situated in the northern part of the Colville valley. Large deposits of limestone and shale occur in the hills around Colville and in places a large amount of work has been done in developing some of these deposits as marble quarries. Large areas of granite and quartzite occur in this locality also. In places clays also occur but they are of poor grade.

Limestone.

On Mr. Ham's ranch one and one-half miles south of the city, a body of limestone occurs which at one time was prospected with a diamond drill. A hole was drilled to a depth of about 100 feet, all the way in limestone. The deposit appears to be quite uniform for this distance both in texture and color. It is fine grained and dark colored, with veins of white calcite through it. These vary in size, but most of them are very small.

This body of limestone is just east of the county road and occurs in a long ridge extending north and south for about a mile and rising at least 50 feet above the road. There appears to be two general characters of limestone in this ridge as far as surface indications are concerned. Along the western slope of the ridge the stone is very fine grained and dark colored, while along the top of the ridge it has a coarser texture and is much lighter in color. A surface sample was collected from each of these parts of this area.

Laboratory Examination.—Both samples of this limestone when pulverized, are very light in color, effervesce rapidly when treated with cold dilute acids and dissolve quickly, the lighter colored one being completely dissolved, while in the case of the other sample, a very small amount of a dark colored, almost black residue remains. The stone is a little harder than many limestones with a slightly flinty appearance and texture.

The following analyses show the chemical composition of these two samples:

ANALYSES OF LIMESTONE, HAM'S FARM, COLVILLE, STEVENS COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	2.20	2.00
Alumina and Iron (Al_2O_3, Fe_2O_3)	1.60	1.08
Lime (CaO)	53.06	53.55
Magnesia (MgO)	1.78	0.76
Loss on ignition	42.76	42.64
Total	101.40	100.03
Calcium carbonate ($CaCO_3$)	94.75	95.52

I. Dark limestone from western slope of ridge.
II. Light colored stone from top of ridge.

In composition the two samples are practically the same and are high grade limestones. They carry but little magnesia and have a high percentage of lime.

The diamond drill cores appear very uniform in texture from the surface down, a distance of 100 feet, this being as far as the drill went. The cores are dark colored, with small seams of white coarsely crystalline calcite quite common. Usually these seams are very thin, about an eighth of an inch, but in some instances they are as much as half an inch in thickness.

Four analyses were made of these diamond drill cores, each sample being from a different depth below the surface.

ANALYSES OF LIMESTONE, HAM'S RANCH, COLVILLE, STEVENS COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.	III.	IV.
Silica (SiO_2)	3.16	14.84	1.96	5.44
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.92	3.40	2.68	1.36
Lime (CaO)	51.22	44.88	48.73	47.87
Magnesia (MgO)	2.15	1.20	3.26	3.96
Loss on ignition	41.95	34.90	42.00	40.37
Total	99.40	99.22	98.63	99.00
Calcium carbonate ($CaCO_3$)	91.46	80.03	87.00	85.48

I. Twenty feet below surface.
II. Thirty-five feet below surface.
III. Sixty feet below surface.
IV. Eighty feet below surface.

The above analyses do not show as much lime as the surface samples do, while the amount of magnesia in the diamond

drill cores is higher than in the surface samples. Number two is especially high in silica and some, at least, of the calcium in this sample must be in the form of a silicate.

Due east of Colville, about four miles, is another body of limestone. On the south and east this limestone is in contact with granite and on the north and west with shale. The limestone is in sections 4, 5, 7, 8, 17 and 18, township 35 north, range 40 east, and sections 12 and 13, township 35 north, range 39 east.

The material mapped as limestone varies much in the different parts of this area. Much of it has a more or less shaley structure and in all probability has but little lime in it. Much of it is crumpled and folded showing plainly the results of metamorphism. Limestone extends well up into Dominion mountain and lies on granite. The limestone taken from the tunnel on the Old Dominion mine is very light, almost white in color.

In section 13, township 35 north, range 39 east, and section 18, township 35 north, range 40 east, are massive deposits of limestone which rise more than 100 feet above the bottom of the gulch. The limestone occurs in contact with granite and the deposit is much broken on the surface. The limestone at this place appears to be very uniform in texture but varies somewhat in color, the predominating one, however, being gray with more or less white mixed through it.

Laboratory Examination.—Two samples of the limestone from this area were examined in the laboratory. One of these came from the large dump at the mouth of the upper tunnel of the Old Dominion mine, which is in the northern part of the area, while the other sample came from section 13, township 35 north, range 39 east, which is the extreme southern part of the area.

The sample from the Old Dominion mine is almost white in color and coarsely crystalline. When treated with cold dilute acid it effervesces but slowly and only partially dissolves.

Thin sections of this stone, when viewed under the microscope, appear considerably clouded. They show but little the cross twinning so common in calcites. Cleavage is especially well shown and many characteristic sections parallel to the face of the rhombohedron are noticeable. The grains vary somewhat

in size, but most of them, however, are from .5 to 1 mm. in diameter.

The samples from the southern part of this area, section 13, township 35 north, range 39 east, are much darker in color than the ones from the Old Dominion mine. They are dark gray and not so coarsely crystalline. When pulverized and treated with cold dilute acid they effervesce but slowly and are only partially dissolved.

Thin sections of this limestone, when viewed under the microscope, show it to be made up of grains which vary in size from those that are not more than .05 of a mm. to those that are as much as .5 of a mm. in diameter. The individual particles are irregular in outline, and interlock very firmly. In ordinary light thin sections have a somewhat clouded appearance and very few cleavage planes are noticeable. In polarized light the polysynthetic twinning of the calcites is quite common.

The following analyses show the chemical composition of the two samples from this area:

ANALYSES OF LIMESTONE FROM EAST OF COLVILLE, STEVENS COUNTY.

CONSTITUENTS.	I.	II.	III.
Silica (SiO_2)	3.98	0.82	3.91
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.41	0.63	1.23
Lime (CaO)	33.07	32.77	30.99
Magnesia (MgO)	21.15	19.02	20.28
Carbon dioxide (CO_2)	.....	46.73	.....
Loss on ignition	41.19	.....	43.72
Total	99.80	99.97	100.13

I. Old Dominion Mine. A. A. Hammer, Analyst.
II. Sec. 13, T. 35 N., R. 39 E. R. W. Thatcher, Analyst.*
III. Sec. 13, T. 35 N., R. 39 E. A. A. Hammer, Analyst.

The above analyses show the samples to be very similar in composition and, on account of the large amount of magnesia and the small amount of lime, to be of no value as materials for use in the manufacture of Portland cement.

Shale.

Shales are very common to the south and east of Colville and cover a very large area. These outcrop along the road

*Washington Geological Survey, Vol. II, p. 120.

south of the limestone on Ham's farm and a sample was collected from section 21, township 35 north, range 39 east. The deposits where exposed along the road have a very uniform appearance and texture.

Laboratory Examination.—This shale is light gray in color, very finely laminated, and has a slightly greasy feel. In cold dilute hydrochloric acid it effervesces slightly, showing the presence of some carbonate.

The following analysis shows the chemical composition of this shale:

ANALYSIS OF SHALE FROM COLVILLE, STEVENS COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	41.28
Alumina (Al_2O_3)	10.31
Iron (Fe_2O_3)	2.33
Lime (CaO)	21.93
Magnesia (MgO)	3.12
Loss on ignition	19.42
Total	98.39

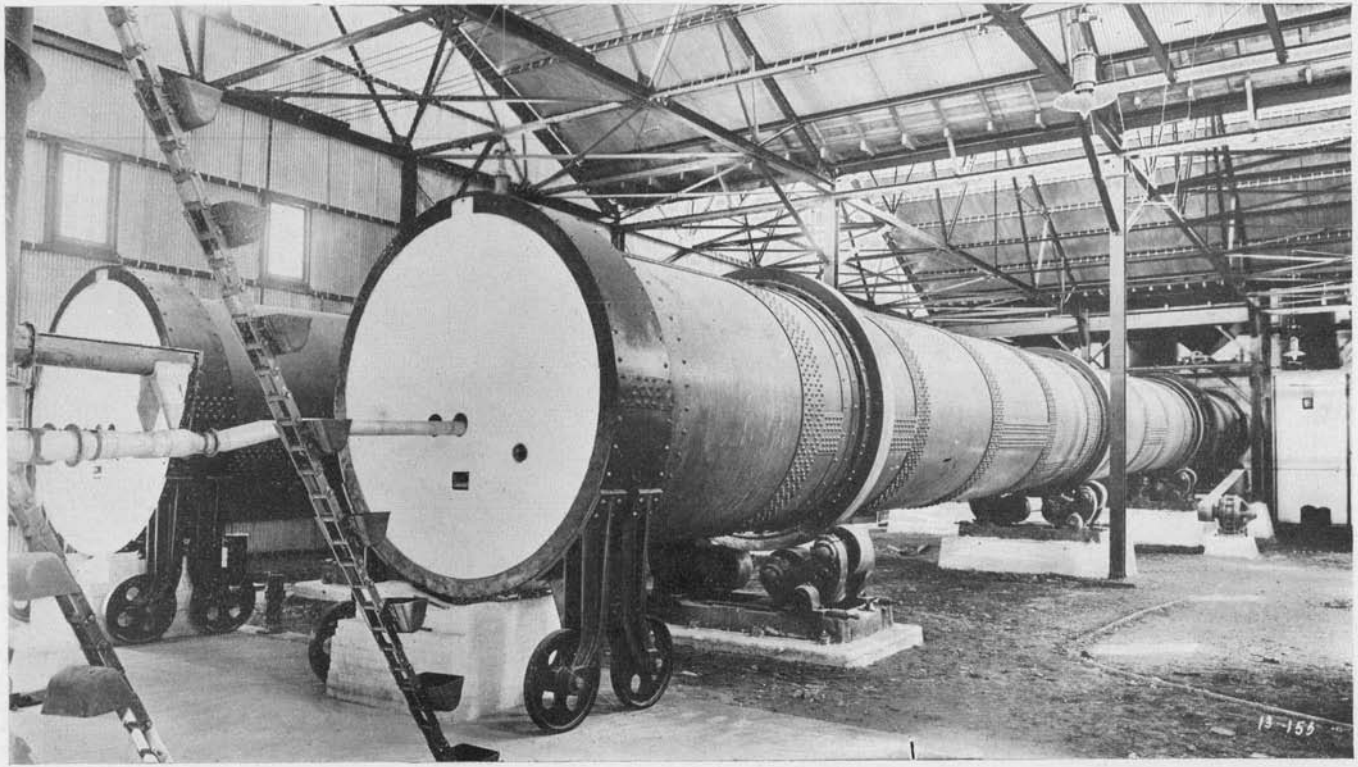
The above analysis shows this shale to have a considerable amount of lime and a low percentage of silica, alumina, and iron. The ratio, nevertheless, between the silica and the alumina plus the iron, is within the limits. The percentage of magnesia is not excessive, providing the limestone with which it is to be mixed is free, or nearly so, from this substance.

MILL CREEK.

The prevailing formations along Mill Creek are shales, with quartzite and some limestone. The shales cover a very large area in the vicinity of Millville and extend up both the north and the south fork of the stream for more than ten miles.

Limestone.

Limestone occurs in several places along Mill Creek. One of these deposits is situated in sections 26 and 35, township 36 north, range 39 east. Other deposits occur in sections 4 and 9, township 36 north, range 40 east, and sections 21, 22, 27, 28 and 33, township 37 north, range 40 east. These deposits are more or less shaley in structure and have the appearance, except in a few places, of being low grade limestones. In some places the deposits are only calcareous shales. The material varies in



Rotary Kiln, 9½ x 140 feet in size, in the Plant of the Inland Portland Cement Company at Metaline Falls.

color and ranges from almost pure white to almost black. In texture it also varies, in some cases being very fine grained, while in others it is coarse.

The following analyses taken from Vol. II, Washington Geological Survey, p. 121, show the composition of this material:

ANALYSES OF LIMESTONE FROM MILL CREEK, STEVENS COUNTY.
R. W. THATCHER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	2.61	3.12
Alumina (Al_2O_3)	.....	.....
Ferric iron (Fe_2O_3)	.....	0.12
Ferrous iron (FeO)	.....	0.81
Lime (CaO)	53.68	52.04
Magnesia (MgO)	0.76	0.67
Carbon dioxide (CO_2)	42.89	43.22
Total	99.94	99.98
Calcium carbonate ($CaCO_3$)	95.85	92.92

I. White limestone.
II. Dark gray limestone.

The above analyses show this limestone to be of very good quality. It has a good percentage of lime and is especially low in impurities of various kinds.

CLUGSTON CREEK.

Clugston Creek rises in the mountains about twelve miles north and three east, of the town of Colville, flows southwesterly and empties into Mill Creek, about two miles south of Echo. From Echo to its source, it flows in more or less of a canyon and is a typical mountain brook. The principal formation along this stream is shale. Near its headwaters, however, large bodies of limestone occur.

Limestone.

On the headwaters of Clugston Creek large bodies of limestone occur, covering a large area. In places the deposits show stratification, while in others they appear massive. The material varies much in color and ranges from almost pure white to almost black. Gray, however, is a very common color. Considerable work has been done in two or three places on these de-

posits with a view to opening them up as marble quarries. Where stratification is shown the deposits are steeply inclined.

Laboratory Examination.—In texture these deposits range from very fine to coarse grained. Thin sections show grains from about .05 of a mm. to those that are as much as 1.5 mm. in diameter. The grains are quite irregular in outline and in ordinary light the sections have a more or less clouded appearance.

The following analyses, which are taken from Vol. II, Washington Geological Survey, pp. 111, 117, show the composition of this material:

ANALYSES OF LIMESTONE FROM CLUGSTON CREEK, STEVENS COUNTY.
R. W. THATCHER, Analyst.

CONSTITUENTS.	I.	II.	III.	IV.	V.
Silica (SiO_2)	0.87	3.49	0.98	0.82	1.89
Iron (Fe_2O_3)	.....	0.24	trace	trace	trace
Lime (CaO)	55.16	51.54	53.96	54.81	42.60
Magnesia (MgO)	0.21	1.11	1.25	0.70	10.05
Carbon dioxide (CO_2)	43.77	42.46	43.76	43.56	44.63
Water at 110°C (H_2O) and undetermined substances	.....	0.16	.....	.....	.....
Total	100.01	100.00	99.95	99.89	100.17
Calcium carbonate ($CaCO_3$)	98.50	91.96	94.57	97.87	76.07

I. White. Jefferson Marble Quarry.
II. Pinkish, Jefferson Marble Quarry.
III. White. Keystone Marble Co. Secs. 1 and 12, T. 37 N., R. 39 E.
IV. Gray. Keystone Marble Co. Secs. 1 and 12, T. 37 N., R. 39 E.
V. Dark gray. Keystone Marble Co. Secs. 1 and 12, T. 37 N., R. 39 E.

The above analyses show the limestone on Clugston Creek, with the exception of sample number five, to be of especially high grade. Number five has so high a percentage of magnesia that it would be of no value in the manufacture of Portland cement. The other samples, however, are all very low in magnesia as well as other impurities.

Shale.

From Echo to near the head waters of Clugston Creek, shales are very abundant. This material varies more or less at different places, in some being very thinly laminated, while in others the layers are thicker and the deposits more massive.

These deposits rise in high bluffs along the stream and extend back from it on either side for several miles. In color, the deposits vary from light to dark gray and in texture they appear to be quite uniform.

Laboratory Examination.—These shales are a little harder than the average shale and are very compact and fine grained. When pulverized, they are light gray in color, and when mixed with water have but little plasticity. When treated with dilute hydrochloric acid there is a slight effervescence which shows the presence of a small amount of some carbonate.

The following analysis shows the composition of what is thought to be an average sample of these shales:

ANALYSIS OF SHALE FROM CLUGSTON CREEK, STEVENS COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	72.64
Alumina (Al_2O_3)	12.70
Iron (Fe_2O_3)	4.66
Lime (CaO)	1.64
Magnesia (MgO)	1.97
Potash (K_2O)	1.43
Soda (Na_2O)	1.30
Loss on ignition	3.54
Total	99.88

The above analysis shows these shales to have a large amount of silica and a small amount of alumina, iron, lime, and magnesia. The amount of silica is so large that a part of it probably exists in the free state or as quartz. The precentage of the alumina and iron as compared with the amount of the silica is small and on account of this fact, mainly at least, this material is not very well suited for use in the manufacture of Portland cement unless some material low in silica and high in alumina and iron is mixed with it.

STRANGER CREEK.

Limestone.

Large bodies of limestone are located on the headwaters of Stranger Creek in sections 22, 23, 24, 25, 26, 27, 34 and 35, township 34 north, range 38 east, and sections 3 and 11, township 33 north, range 38 east. This limestone occurs in large bodies and in places has been quarried for marble. These deposits vary much in color and range from pure white to light gray. The

deposits are not so badly broken here as they are in most parts of Stevens county.

Laboratory Examination.—In texture these deposits range from very fine grained to very coarse. The individual grains vary more or less in size and range from those with a diameter of about 0.15 of a mm. to those that are as much as 1.5 mm. in diameter. When treated with cold dilute hydrochloric acid, it effervesces but very little.

The following analyses show the chemical composition of a number of samples from these deposits:

ANALYSES OF LIMESTONE FROM STRANGER CREEK, STEVENS COUNTY.

CONSTITUENTS.	I.	II.	III.	IV.
Silica (SiO_2)	0.91	0.98	1.12	0.56
Alumina and Iron (Al_2O_3, Fe_2O_3)	.....	.....	0.96	0.40
Lime (CaO)	31.80	30.08	29.56	55.15
Magnesia (MgO)	20.68	22.21	23.62	0.79
Carbon dioxide (CO_2)	46.64	46.70	.....	.....
Loss on ignition	.....	.....	43.61	43.12
Total	100.03	99.97	98.27	100.02

I. White. Crystal Marble Quarry. Wash. Geol. Survey, Vol. II, p. 114. R. W. Thatcher, Analyst.

II. Dark gray. Crystal Marble Quarry. Wash. Geol. Survey, Vol. II, p. 114. R. W. Thatcher, Analyst.

III. Between north fork Stranger and Riddle creeks. A. A. Hammer, Analyst.

IV. Jacobs' farm, one mile north of Crystal Marble Quarry. A. A. Hammer, Analyst.

The above analyses show a very large amount of magnesia in all the samples except number four, and this one has scarcely any. From the above, it would appear that the deposits in this locality are, in the main at least, highly magnesian and of no value for Portland cement.

Shale.

Shales are very abundant on the headwaters of Stranger and along Riddle and Lafoty creeks. These shales are dark gray in color, very fine grained, finely laminated, and have a rough gritty feel. They are broken into very small pieces and where they are much weathered are quite soft. A sample of these shales was collected along Jacobs road in section 24, township 34 north, range 38 east.

Laboratory Examination.—These shales have had considerable calcium carbonate deposited in the numerous cracks and crevices which occur in them, so that the edges of many of the small pieces are covered with a thin coating of this material.

The following analysis shows the chemical composition of this material:

ANALYSIS OF SHALE, JACOBS ROAD, BETWEEN RIDDLE AND LAFOTY CREEKS, STEVENS COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	59.24
Alumina (Al_2O_3)	7.36
Iron (Fe_2O_3)	3.00
Lime (CaO)	11.08
Magnesia (MgO)	2.80
Loss on ignition	15.91
Total	99.39

The above analysis shows a very small amount of alumina in this shale and about an average amount of silica, which indicates a considerable amount of free silica.

COLUMBIA RIVER VALLEY.

The Columbia river forms the western line of Stevens county from its border to the place where Kettle river empties into the Columbia river. Along the eastern side of the Columbia, for its entire distance across Stevens county, is a more or less well developed valley. In places this valley has a considerable width, while in others the hills rise directly from the water's edge. Beginning a few miles south of Kettle Falls, limestone deposits are common through that part of the valley to the north. The deposits are not continuous but occur in more or less isolated masses. Around Kettle Falls limestones are not very common and the area covered is comparatively small. The frequency of occurrence and the amount of the limestone increases to the north until around Northport it is very common and occurs in very large quantities.

Shales and clays are also found in many places throughout this valley, in some cases being in close proximity to limestones and in others being a considerable distance from them.

KETTLE FALLS.

Kettle Falls is situated on the east bank of the Columbia river, just where the Colville river empties into it. Its nearest

railroad point is Meyers Falls, on the Spokane Falls and Northern Railway, which is about two and one-half miles distant. Limestones, shales and clays are all found within a few miles of the town.

Limestone.

About two miles south of Kettle Falls on Col. Fish's place, limestone occurs and lime was burned here at one time. The deposits cover a considerable area here, outcropping at least three-fourths of a mile south and west along the Columbia river. The deposits occur in low rounded knolls which rise only a few feet above the road and not far above the river. The limestone at the northern end of this deposit is dark gray in color and crystalline throughout. To the naked eye the calcite crystals appear small but show well marked cleavage faces. The deposit at this point shows well marked stratification, the different layers being in some cases not more than an eighth of an inch in thickness. The limestone at the southern end of the deposit along the Columbia river is a little lighter colored and finer grained than the northern end of the deposit.

Laboratory Examination.—When pulverized these samples are almost white in color. They effervesce rapidly in dilute hydrochloric acid and are practically all dissolved.

The following analyses show the chemical composition of the two samples analyzed from the deposit:

ANALYSES OF LIMESTONE FROM KETTLE FALLS, STEVENS COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	0.38	1.56
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.28	0.64
Lime (CaO)	54.06	54.62
Magnesia (MgO)	2.03	1.12
Loss on ignition	43.15	42.34
Total	99.86	100.28
Calcium carbonate ($CaCO_3$)	96.53	97.53

I. Limestone from northern end of deposit.
II. Limestone from southern end of deposit, along the Columbia river.

The above analyses show this limestone to be especially high in lime and low in impurities of all kinds. The only im-

purity that amounts to anything is the magnesia, and in number one, even where it is most, the amount is small and would not hurt the limestone for Portland cement purposes.

The largest body of limestone in the vicinity of Kettle Falls is situated to the south of the town about six or seven miles, in Peaceful valley. It lies in sections 27, 34, and 35, township 35 north, range 37 east, and sections 2 and 3, township 34 north, range 37 east. This body of limestone has an approximate length north and south of about two miles and an average width of about 800 feet. It appears to be steeply inclined and dip to the east. Dark colored slightly grayish shales occur on either side of it.

The limestone is very fine grained and of quite uniform texture. It is grayish in color, has a somewhat flinty appearance, and is affected but slowly by atmospheric agencies.

Laboratory Examination.—In cold dilute hydrochloric acid it effervesces slowly but is finally practically all dissolved. It is quite brittle, easily pulverized, the powder being almost white in color.

The following analysis shows the chemical composition of this limestone:

ANALYSIS OF LIMESTONE FROM PEACEFUL VALLEY, STEVENS COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	1.70
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.56
Lime (CaO)	54.57
Magnesia (MgO)	0.56
Loss on ignition	42.18
Total	99.57
Calcium carbonate ($CaCO_3$)	97.44

The above analysis shows this to be a very fine grade of limestone for use in the manufacture of Portland cement. It is practically free from magnesia and contains a very high percentage of lime.

Clay.

Large clay deposits are found at Kettle Falls and nearby. They occur on both sides of the Columbia river and extend along it for a considerable distance. These clays are all river deposits and in places are interstratified with layers of sand, while in others they are quite free from it. A large body of this clay has

been exposed along the bank of the Columbia river where the wagon road has been graded down to the ferry. The clay as exposed at this place is not entirely uniform in composition but contains some of the sandy layers mentioned above. The deposit is covered with from ten to fifteen feet of gravel and this would have to be removed in order to get the clay. The deposit has a thickness of more than 40 feet and occurs in large quantities at this place.

Laboratory Examination.—This clay is light gray in color, very fine grained and free from gritty material. It absorbs water rapidly and slakes, breaking into a mass of very fine particles. It changes but little in color when pulverized.

The following analysis shows the chemical composition of a sample of this clay:

ANALYSIS OF CLAY FROM KETTLE FALLS, STEVENS COUNTY.

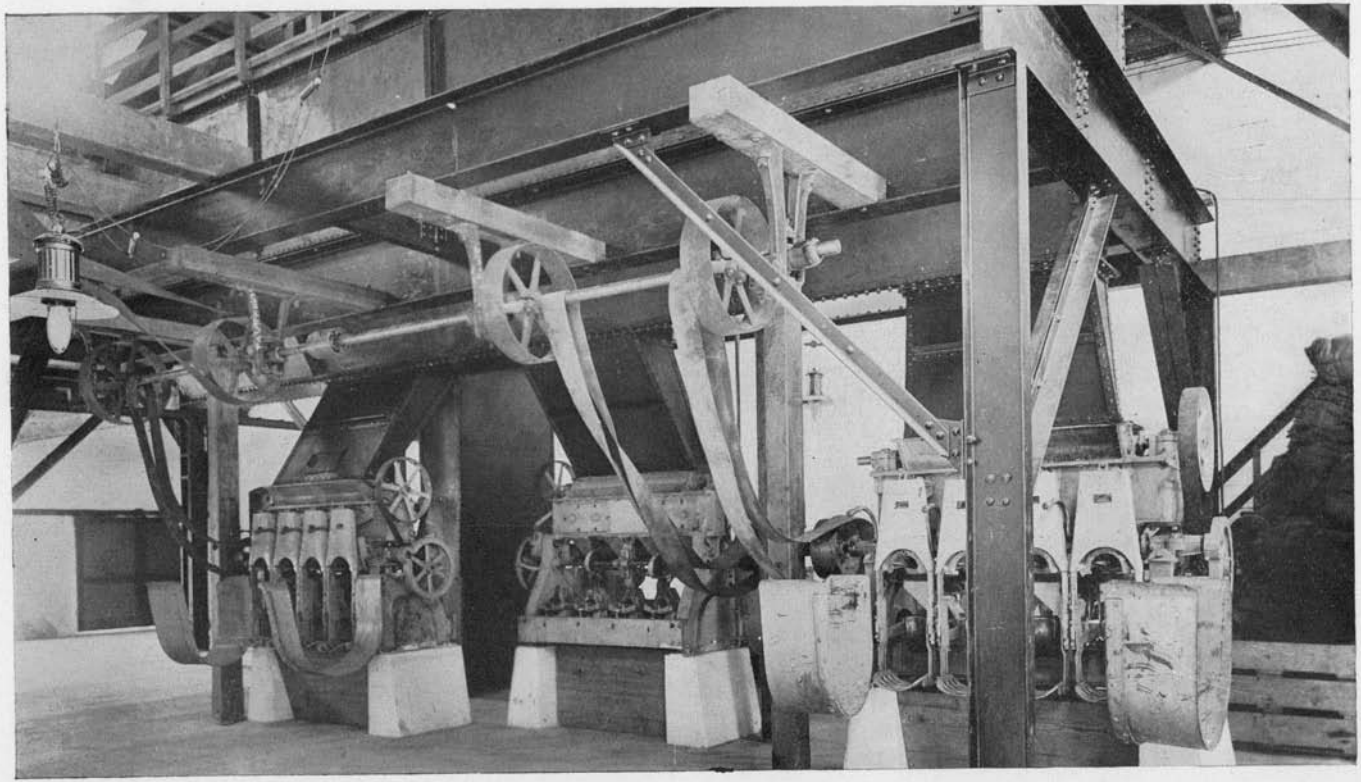
Silica (SiO_2)	56.98
Alumina (Al_2O_3)	17.74
Iron (Fe_2O_3)	7.22
Lime (CaO)	5.25
Magnesia (MgO)	4.08
Potash (K_2O)	1.31
Soda (Na_2O)	0.86
Loss on ignition	6.07
Total	99.51

The above analysis shows this clay to have a very good ratio between the silica and alumina. The fluxes are high enough so it should fuse at a fairly low temperature. The amount of magnesia is a little high. This clay could be used only with a limestone in which the amount of magnesia is low or the amount in the finished product would go above 5 per cent.

Shale.

Large bodies of shale occur south of Kettle Falls in sections 23, 24, 25 and 26, township 35 north, range 37 east. Samples of these shales were obtained in cuts along the Heidigger road, one sample being about four and one-half miles from Kettle Falls and the other about six miles.

The sample which occurs nearest Kettle Falls is badly weathered and occurs only in very small and thin pieces. It is medium gray in color and very fine grained. The other sample



Automatic Packing Machines in the Plant of the Inland Portland Cement Company at Metaline Falls.

from this locality is very similar to this one, only that it is not so badly decomposed. It is very finely laminated, fine grained, and has more of a smooth greasy feel.

Laboratory Examination.—Each of these are soft and easily pulverized. The powder is light gray in color.

The following analyses show the composition of this shale:

ANALYSES OF SHALE FROM SOUTH OF KETTLE FALLS, STEVENS COUNTY.

A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	72.01	58.15
Alumina (Al_2O_3)	12.52	16.90
Iron (Fe_2O_3)	4.35	9.22
Lime (CaO)	2.02	2.15
Magnesia (MgO)	1.99	3.02
Potash (K_2O)	1.80	1.71
Soda (Na_2O)	1.36	1.36
Loss on ignition	3.18	4.12
Total	99.23	99.63

I. Shale four and one-half miles south of Kettle Falls.
II. Shale six miles south of Kettle Falls.

The analyses given above show number one to be very siliceous with a low percentage of iron and alumina, and on account of this it would be of little value for cement purposes. The sample analyzed, however, is from the surface and in all probability a part of the silica is in the free state as particles of fine sand. The deposit justifies careful prospecting at any rate.

Number two, as shown by the above analysis, is considerable lower in silica and higher in alumina, iron and magnesia. The ratio between the sum of the alumina and iron and the silica is a very good one and within the limits allowed. The amount, 3.02 per cent. of magnesium oxide in this shale, is equivalent to 6.32 per cent. of magnesium carbonate ($MgCO_3$), which is a little high, but if it is used with a limestone low in magnesia the amount in the mixture would still be less than the allowable amount.

To all appearances this is a good shale. The amount of fluxes present is sufficient so that the shale would fuse at a low temperature. It would not be hard to pulverize as it is quite

brittle. The amount of iron is so great, however, that only a dark colored cement could be manufactured.

The shales which occur in contact with the limestone deposits in Peaceful valley appear very similar to those on the north and are probably a continuation of them.

The analyses show good materials in the vicinity of Kettle Falls from which to manufacture Portland cement.

MARCUS.

Across the Columbia river from the town and distant from it about three-fourths of a mile, is a deposit of clay, a sample of which was analyzed. It was obtained from a cut along the Great Northern Railway and was dark gray in color, fine grained and compact.

The following analysis shows the chemical composition of this clay:

ANALYSIS OF CLAY FROM NEAR MARCUS, STEVENS COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	50.68
Alumina (Al_2O_3)	19.79
Iron (Fe_2O_3)	9.45
Lime (CaO)	6.48
Magnesia (MgO)	3.15
Potash and Soda (K_2O, Na_2O)	2.31
Loss on ignition	7.20
Total	99.11

This clay is low in silica, high in alumina, iron, and calcium and is not suitable for use in the manufacture of Portland cement unless it should be mixed with a more silicious material.

EVANS.

Evans is near the Columbia river about four miles north and three miles east of Marcus. Limestones and shales occur here and the Idaho Lime Co. has located a plant at this point and is burning lime. There are three kilns, each having a capacity of about 100 barrels a day. The Spokane Falls and Northern Railway, a branch of the Great Northern, gives this plant good shipping facilities.

Limestones.

The limestones in this locality occur in connection with shales and are practically surrounded by them. The limestones occur in low knolls, there being a number of more or less sep-

arated masses. In one or two places igneous dikes are found cutting through the limestone.

The deposits are uniformly very fine grained. The stone is light gray in color with occasional dark streaks through it, cleaves readily in two directions and is very brittle. It burns to a nice white lime.

Laboratory Examination.—When pulverized it is almost pure white, readily soluble in dilute acids and effervesces very rapidly.

The following analyses shows the chemical composition of this limestone:

ANALYSES OF LIMESTONE FROM EVANS, STEVENS COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	0.96	1.15
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.20	trace
Lime (CaO)	55.10	54.21
Magnesia (MgO)	0.36	trace
Loss on ignition	43.28	43.64
Total	99.90	99.00
Calcium carbonate ($CaCO_3$)	98.39	96.80

The above analyses show this to be a very pure, high grade limestone, well suited for the burning of lime or the manufacture of Portland cement.

Clay.

A sample of clay was obtained along the road about one-half mile north and a little east of Evans. This clay is light gray in color, fine grained, and finely stratified. The indications are that this clay covers a considerable area and that there is a large body of it.

The following analyses show the chemical composition of this material.

ANALYSES OF CLAY FROM EVANS, STEVENS COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	57.68	56.48
Alumina (Al_2O_3)	22.60	20.52
Iron (Fe_2O_3)	8.26	7.16
Lime (CaO)	5.95	4.18
Magnesia (MgO)	2.08	3.49
Alkalies (K_2O, Na_2O)	undt.	undt.
Loss on ignition	1.69	5.10
Total	98.26	96.93

The amount of silica in this clay is a trifle low, while the amount of iron and alumina is a little high. This makes the ratio of the silica to the iron and alumina low, the percentage of silica being about twice that of the iron and alumina together.

Shale.

Shales are very abundant in this locality and, while no samples were analyzed, they have the appearance of being just what is needed to mix with the clay to increase the silica content. The shales east of Bossburg, which are only three miles north of Evans, contain 10 per cent. more silica and about 12 per cent. less iron and alumina than does the clay at Evans. By mixing the clay and shale in certain proportions the proper ratio between the silica and the iron and alumina could easily be obtained. It is very probable, however, that a careful examination of the shale around Evans would show that this is equally as good.

BOSSBURG.

Limestone.

Limestones occur here on either side of the Columbia river and extend with slight breaks as far as Northport.

West Side of Columbia.—The deposits on the west side of the river, in the vicinity of Bossburg, vary in color from a fairly pure white to various shades and markings of gray and white. They also vary somewhat in texture and range from fine grained to quite coarse grained. The deposits show distinct stratification and lie almost horizontal.

Laboratory Examination.—The samples when pulverized are almost white, effervesce rapidly in acids, and are entirely dissolved. The samples, the analyses of which are given here, are from about two miles almost due north of Bossburg. The deposits on this side of the Columbia river are very extensive, covering a large area and in places, at least, being many feet in thickness. No clays or shales were found in this locality which had the appearance of being suitable for use in the manufacture of Portland cement.

The following chemical analyses show the composition of samples taken about two miles north of Bossburg on the west side of the Columbia river:

ANALYSES OF LIMESTONE TWO MILES NORTH OF BOSSBURG, STEVENS COUNTY.

CONSTITUENTS.	I.	II.	III.
Silica (SiO_2)	2.49	0.13	0.98
Alumina (Al_2O_3)	0.49	.....	0.36
Ferric Iron (Fe_2O_3)	0.49	.....	.....
Ferrous Iron (FeO)	trace	.....	.....
Lime (CaO)	31.56	54.95	54.48
Magnesia (MgO)	18.56	0.54	0.79
Carbon dioxide (CO_2)	45.91	44.22	.....
Water at 110° C (H_2O)	trace	.....	.....
Water above 110° C (H_2O)	trace	.....	.....
Loss on ignition	.....	.....	43.26
Total	99.95	99.84	99.87
Calcium carbonate ($CaCO_3$)	56.35	98.12	97.28

I. White limestone. R. W. Thatcher, Analyst.*
II. Light gray limestone. R. W. Thatcher, Analyst.*
III. White limestone. A. A. Hammer, Analyst.
*Shedd, Building and Ornamental Stones of Washington, Wash Geol. Survey, Vol. 2, pp. 129-130.

The above analyses show a considerable difference in composition. Sample number one is high in magnesia and low in lime. This sample also has more silica than either of the other two. The amount, however, even in this sample, is not great enough to be detrimental. The amount of magnesia, nevertheless, is so great that this sample is of no value for Portland cement.

Samples numbered two and three are much better limestones and, in fact, each of these is very high grade. They are practically free from silica and magnesia and high in lime. Either of these samples represent first class Portland cement material. Number one and two are from section 13, township 38 north, range 37 east, while number three is from section 18, township 38 north, range 38 east.

East Side of Columbia.—The deposits on the east side of the Columbia river at Bossburg are not so extensive as those on the west side. The largest body has an extent north and south of about two miles and a width east and west of about one mile. This body of limestone is situated in sections 27, 28, 33 and 34, township 28 north, range 38 east. Along the western side this de-

posit rises in steep high bluffs showing a great thickness of lime. On the east side it occurs in contact with shales and occasionally conglomerates.

The limestone is very light gray in color, coarsely crystalline, and breaks quite easily. It shows well defined stratification planes along which it separates very readily. It shows but little the effects of atmospheric agencies, the surface material appearing practically the same as that some distance below the surface.

Laboratory Examination.—This limestone, when pulverized, is white in color, readily soluble in dilute acids with rapid effervescence, and completely dissolved. Thin sections, when viewed under the microscope, show a more or less clouded appearance. The grains vary much in size and appearance. The coarser ones show polysynthetic twinning, the twin lamellae being of medium thickness. In many cases the lamellae are more or less curved and show the effects of pressure. The sections show marked relief and in a few places slight pleochroism. In some places cleavage cracks, which intersect at the usual angle for calcite, are very common. With crossed nicols strong double refraction is shown. The interference colors are of a high order of pale gray.

The following analyses show the chemical composition of the limestone in this deposit:

ANALYSES OF LIMESTONE FROM EAST SIDE OF COLUMBIA AT BOSSBURG, STEVENS COUNTY.

A. A. HAMMER, Analyst.

CONSTITUENTS	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Silica (SiO_2)	0.86	0.51	0.65	0.78	0.65	0.51	1.13	0.96	1.41
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.26	0.34	0.19	0.51	0.31	0.45	0.26	0.20	0.41
Lime (CaO)	54.86	54.26	54.32	53.90	54.64	54.85	53.65	54.16	53.16
Magnesia (MgO)	0.96	1.15	0.96	1.08	0.81	trace	1.46	1.06	0.96
Loss on ignition	42.50	42.30	42.54	42.00	42.92	43.10	42.68	43.00	43.16
Totals	99.44	98.56	98.66	99.17	99.33	98.91	99.18	99.38	99.10
Calcium carbonate ($CaCO_3$)	97.65	96.48	96.69	95.94	97.57	97.94	95.80	97.71	94.94

The above analyses show this to be a very high grade limestone. It is high in lime and very low in impurities of various

kinds. The amount of magnesia is so low that it will not in any way injure the limestone for use in the manufacture of Portland cement.

Clay.

Clay is found in large quantities in the town of Bossburg and around it. This clay is very fine grained, light gray in color, and finely stratified. While it is hard to say positively, the indications are that the deposit has a considerable thickness. The beds appear to be quite uniform in composition, are not very hard and are of alluvial origin.

Laboratory Examination.—This clay is very fine grained, slakes rapidly, breaking into a mass of very fine particles practically free from gritty materials. It has only a medium degree of plasticity and low tensile strength.

The following analyses show the chemical composition of the clay in and around Bossburg.

ANALYSES OF CLAY FROM BOSSBURG, STEVENS COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	55.90	60.14
Alumina (Al_2O_3)	20.69	20.00
Iron (Fe_2O_3)	7.55	5.68
Lime (CaO)	3.63	4.07
Magnesia (MgO)	2.32	2.85
Alkalies (K_2O, Na_2O)	undt.	undt.
Loss on ignition	6.40	4.50
Total	96.49	97.24

The above analyses show that one of these samples is a little low in silica, while the other has about an average amount. The amount of alumina is about the average for ordinary clays, but the iron is somewhat higher than it is in most clays. This gives a ratio, a trifle low, between the silica and the iron and alumina, and to get the best results some material should be used with this clay that has more silica and less iron and alumina.

Shale.

Large bodies of shale occur in the vicinity of Bossburg, especially a short distance east of the town. The shales here are a continuation of those to the south around Evans. The

limestone is in contact with these shales and appears to be on them.

Laboratory Examination.—These shales are not so badly broken as most of those in Stevens county. They occur in quite thin layers, however, are quite soft, and easily pulverized. In color they vary somewhat, dark gray, silver gray, and green being very common. On the edges of many of the pieces a thin layer of quartz occurs, this having been deposited in the crevices in the shale.

The following analyses show the chemical compostion of two samples of this shale taken from different places:

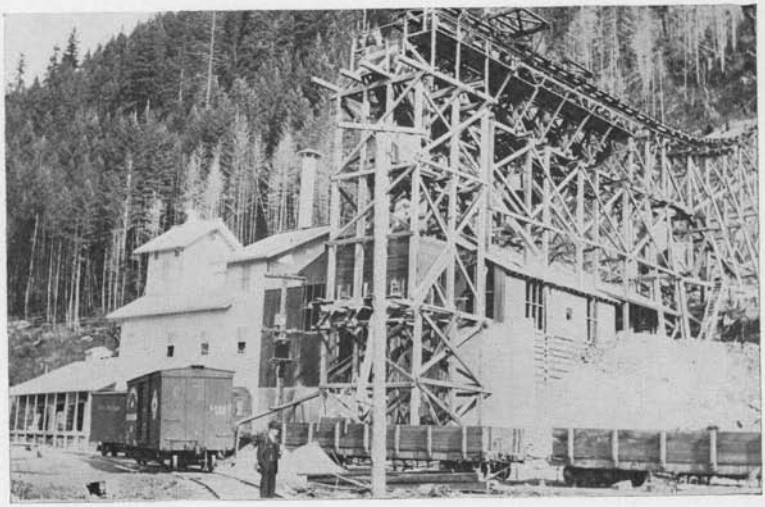
ANALYSES OF SHALE FROM NEAR BOSSBURG, STEVENS COUNTY.
A. A. HAMMER, Analyst.

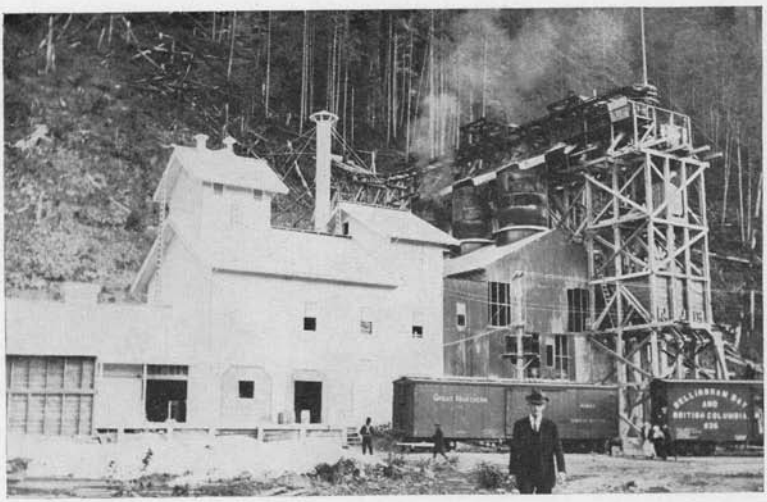
CONSTITUENTS.	I.	II.
Silica (SiO_2)	66.68	57.56
Alumina (Al_2O_3)	10.82	22.48
Iron (Fe_2O_3)	5.02	10.40
Lime (CaO)	4.62	0.45
Magnesia (MgO)	1.31	3.14
Alkalies (K_2O, Na_2O)	undt.	undt.
Loss on ignition	7.22	2.78
Total	95.67	96.81

I. One mile east of Bossburg.
II. East of Bossburg, Bonanza Mine.

The above analyses show that the sample from one mile east of Bossburg contains a high percentage of silica, a very small amount of alumina, and a medium amount of iron. The amount of magnesia is also very low. The sample from the Bonanza mine has much the same composition as the clays from Bossburg. The alumina, the iron, and the magnesia are, however, all of them a little higher than they are in the clay.

A mixture of clay and the shale one mile east of Bossburg, in certain proportions, would give a good ratio between the silica and the alumina and iron and would make a good material to use with the Bossburg limestone for Portland cement. A careful prospecting of the shales in this locality would in all probability show many places where they would have such a composition that they could be used without the clay.





Plant of the International Lime Company, near Kendall, Whatcom County.

RYAN.

Ryan is about six miles northeast from Bossburg on the Spokane Falls and Northern Railway. Limestone, shale, and tufa are all found in this locality. Shale is very abundant between Bossburg and Ryan, while the limestone occurs over comparatively small areas only. On the north side of the Columbia river from Ryan are large bodies of limestone but no samples of these were analyzed, but they appear very similar to those on the south side of the river.

Limestone.

The limestone at Ryan is an isolated mass covering a comparatively small area. There is a considerable quantity, however, of this material, as a thickness of from 150 to 200 feet is shown. This limestone is in section 12, township 38 north, range 38 east. This deposit shows somewhat of a bedded structures in some cases, thin layers of light and dark colored material alternating.

Laboratory Examination.—This limestone is very fine grained and a little harder than the average limestone. It is not hard to pulverize, however, as it seems to be somewhat brittle. When pulverized and treated with cold dilute hydrochloric acid, it effervesces rapidly and is completely dissolved.

The following analysis, taken from Vol. II, Annual Report Washington Geological Survey, p. 131, shows the chemical composition of this limestone:

ANALYSIS OF LIMESTONE FROM RYAN, STEVENS COUNTY.
R. W. THATCHER, Analyst.

Silica (SiO_2)	1.00
Lime (CaO)	53.96
Magnesia (MgO)	1.60
Carbon dioxide (CO_2)	43.27
Water at 110° C (H_2O)	trace
Total	99.83
Calcium carbonate ($CaCO_3$)	96.36

The above analysis shows this to be a very high grade limestone, almost free from impurities of all kinds. It does contain a small amount of magnesia, but the amount is so small that it would not hurt this stone seriously for Portland cement or for the manufacture of lime.

NORTHPORT.

Northport is in the extreme northern part of Stevens county on the Columbia river and the Spokane Falls and Northern Railway. The valley at this point is narrow, low hills coming down close to the river. Large areas in this part of Stevens county are covered with limestones. These deposits also have great thickness, in many cases hundreds of feet, so that the amount of limestone throughout this part of the county is practically inexhaustible. On each side of the river the limestone constitutes almost the whole of the country rock, especially of the lower hills along the river. At higher altitudes farther back from the river, other kinds of rock become more common and shales, slates and igneous rocks of various kinds are found. The limestone in places lies on the slates. A few miles south of town a good example of this occurs.

Limestone.

In places the limestone deposits contain small dikes of igneous material cutting through them. These dikes vary in thickness and range from those that are a fourth of an inch to those that are as much as a foot and a half and, in some few cases, perhaps more. In some of the deposits these dikes are very common. The limestones through this part of the country vary both in color and in texture. In the main, they show but little signs of stratification and have usually undergone considerable metamorphism. No fossils were found in them and hence their age is not known.

About two miles southwest from Northport limestones have been quarried and used as a flux at the Northport smelter. The limestone occurs at this place in a high bluff that rises fifty feet or more above the level of the railroad track. A large face is exposed in the quarry as it extends along the bluff for a distance of 125 feet. The stone here is very compact and almost pure white in color. The quarry face shows a number of small dikes of a dark colored igneous material cutting through the limestone.

Another sample of limestone was obtained about two miles east of the quarry and about two and a half miles south of Northport. Here are large bodies of limestone of much the same character as those farther west, except that they are a little darker in color. At this place they rest on a dark colored slate or shale.

Laboratory Examination.—The limestone from around Northport varies more or less in color, some of it being pure white, some of it light and some dark gray. In texture it is mostly fine grained. With the naked eye innumerable very small glistening particles are visible and with the aid of a hand glass the samples are seen to be made up largely of a mass of very fine crystals. It effervesces readily in cold dilute hydrochloric acid and is completely dissolved.

The following analyses show the chemical composition of two samples from this locality:

ANALYSES OF LIMESTONE FROM NORTHPORT, STEVENS COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	1.98	6.41
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.40	2.09
Lime (CaO)	52.25	51.51
Magnesia (MgO)	2.92	trace
Loss on ignition	42.87	40.13
Total	100.42	100.14
Calcium carbonate ($CaCO_3$)	93.30	91.96

I. Limestone from old quarry two miles southwest of town. Used by Northport smelter.
II. Limestone from about three miles south of town.

The above analyses show each of these samples to be very good limestone. Number one is practically free from iron and alumina, but has some magnesia, while in number two there is no magnesia but more iron, alumina, and silica.

Clay.

Clays in greater or lesser amounts occur in a number of places around Northport. In some cases they are in close prox-

imity to the limestones, while in others they are some distance from them. They are alluvial deposits and may occur along the Columbia river or some distance from it at higher altitudes.

Two and one-half miles above Northport, along the Columbia river, is a large body of clay which is well exposed where the railroad cuts through it. This clay has a blue color, especially when wet, but is grayish when dry. The deposit shows well marked stratification, the layers varying much in thickness and in composition. Some of the layers are very sandy while others consist of a very fine grained plastic clay which is practically free from gritty materials.

Two miles and a half south of Northport, on the bench above the town, clays occur. In section 17, township 39 north, range 40 east, is a clay deposit that was used at one time in the manufacture of brick. There is shown in the old opening which was made at the time the brick yard was in operation, an exposure thirty feet in thickness and fifty feet horizontally of this clay. The deposit is distinctly stratified, and very uniform throughout. This same clay is found outcropping in a number of places along the small creek which flows along here and the indications are that there is a large body of it.

Across the Columbia river from Northport is a flat bench comprising several hundred acres. Clays are known to occur at various places over this area and a short distance from the railroad bridge across the Columbia river, the railroad has cut into them. The deposit at this place appears to be very uniform throughout. It is distinctly stratified, the individual layers being thin, in most cases an inch or less in thickness.

The sample collected is from section 36, township 40 north, range 39 east. The clay on this bench, wherever it was examined appeared to be of the same general character. At the mouth of Sheep creek, where it empties into the Columbia, this same clay outcrops. It is quite probable that there are large deposits of clay occurring in this bench.

Laboratory Examination.—The following analyses show the chemical composition of the samples of clay from Northport:

ANALYSES OF CLAYS FROM NORTHPORT, STEVENS COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.	III.
Silica (SiO_2)	59.76	57.16	56.72
Alumina (Al_2O_3)	17.29	16.10	15.69
Iron (Fe_2O_3)	5.71	8.26	9.34
Lime (CaO)	2.94	4.15	4.43
Magnesia (MgO)	4.11	4.06	3.13
Potash (K_2O)	1.80	1.46	1.19
Soda (Na_2O)	1.51	1.13	1.09
Loss on ignition	6.86	7.13	6.64
Total	99.98	99.45	98.23

I. Clay, two and one-half miles south of Northport.
II. Clay, two and one-half miles northeast of Northport.
III. Clay, across Columbia river from Northport.

Number one is very light yellowish in color, fine grained and free from gritty material. It absorbs water rapidly and slakes, separating into a mass of very thin flat particles. It has good plasticity and when dry has a slightly gritty feel. The above analysis shows it to have about the average composition of an ordinary brick clay except that the percentage of magnesia is a little high. The ratio between the alumina and the silica is good. The amount of fluxing substances is sufficient to cause it to fuse at a low temperature and the amount of iron is not excessive. The amount of magnesia in this clay is above the average for clays that are being used in the manufacture of Portland cement. The maximum amount of magnesium carbonate ($MgCO_3$) allowable in the raw material is 5 to 6 per cent. and 4.11 per cent. of magnesium oxide (MgO) is equivalent to 8.63 per cent. of the carbonate ($MgCO_3$). This is high, but if it were used with a limestone entirely free from magnesia, it might be kept within the limit.

Sample number two is fine grained and free from gritty material. It was taken, however, from the layers in the deposit that appeared to have the least sand in them and would not represent an average of the deposit. It has a slightly bluish tinge, absorbs water and slakes rapidly, breaking into a mass of

very fine particles. It has but little of that slick feel so common to the best grades of clay. The chemical analysis given above shows nothing very striking about this clay. It has a little higher percentage of iron than number one, with a little less silica and alumina. Like number one, it is high in magnesia and could only be used with limestone entirely free, or nearly so, from magnesia.

Clay number three is very fine grained and free from gritty material. It absorbs water rapidly and slakes completely, first separating into a mass of very thin layers, showing very fine lamination. This clay has a little smoother feel than either of the others from this locality, and has good plasticity. When dry it is hard and brittle.

In composition, this clay is very similar to the other two from Northport. It does contain a little less magnesia, however, which is a point in its favor. The amount of iron that it contains is great enough so that, under ordinary conditions at least, only a dark colored cement could be made if this clay were used.

These clays are all very similar in composition and, if it were not for the magnesia that they contain, they would be excellent clays to use in the manufacture of Portland cement.

Shale.

Shale and slate are found on both sides of the Columbia river at Northport. On the north side of the river along Sheep creek, formations of this character are exposed. On the south side of the river on the bluff along the Northport and Deep creek road, shales are exposed. A sample of this shale was collected about one mile from Northport along this road.

Laboratory Examination.—This shale is dark gray in color, very fine grained, and thinly laminated. It is easily pulverized and has a gritty feel.

The following analysis shows the chemical composition of the shale from this locality:

ANALYSIS OF SHALE FROM NORTHPORT, STEVENS COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	82.64
Alumina (Al_2O_3)	7.52
Iron (Fe_2O_3)	5.26
Lime (CaO)	0.99
Magnesia (MgO)	0.96
Loss on ignition	2.23
Total	99.60

This shale, as shown by analysis, is very high in silica and low in alumina and is not a suitable material to use in the manufacture of Portland cement. The sample analyzed, however, was from the surface and much weathered, which in all probability accounts at least partially for the high percentage of silica.

DEEP CREEK.

Limestone and shale are very common along Deep creek. For three or four miles up the creek from its mouth nothing but shale was found on either side of it for a distance of about two miles, where limestones are reached on the south. Granite is also very common along Deep creek covering large areas.

Limestone.

Limestone occurs in sections 24, 25, and 36, township 39 north, range 40 east, and sections 19, 20, 21, 28, 29, and 30, township 38 north, range 41 east. Another large area has its southern limit about the southern end of Deep lake and extends to the northward more than ten miles or to the international boundary. The deposits along Deep creek vary more or less in texture and in color. In some places the deposits are pure white and in one place they have been worked as a marble quarry.

Laboratory Examination.—The sample from the marble quarry is very fine grained and not very hard. This sample was not analyzed, but it probably contains a considerable amount of magnesia, as it is dissolved but very slowly by cold dilute hydrochloric acid.

The other sample from the Deep creek area was almost white in color and much coarser grained than the one from the marble quarry. When pulverized and treated with cold dilute hydrochloric acid it effervesces rapidly and is completely dissolved.

The following analysis shows the chemical composition of this sample:

ANALYSIS OF LIMESTONE FROM DEEP CREEK, STEVENS COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	1.76
Alumina and Iron (Al_2O_3, Fe_2O_3)	trace
Lime (CaO)	55.37
Magnesia (MgO)	trace
Loss on ignition	42.50
Total	99.63
Calcium carbonate ($CaCO_3$)	98.85

From Sec. 29, T. 38 N., R. 41 E.

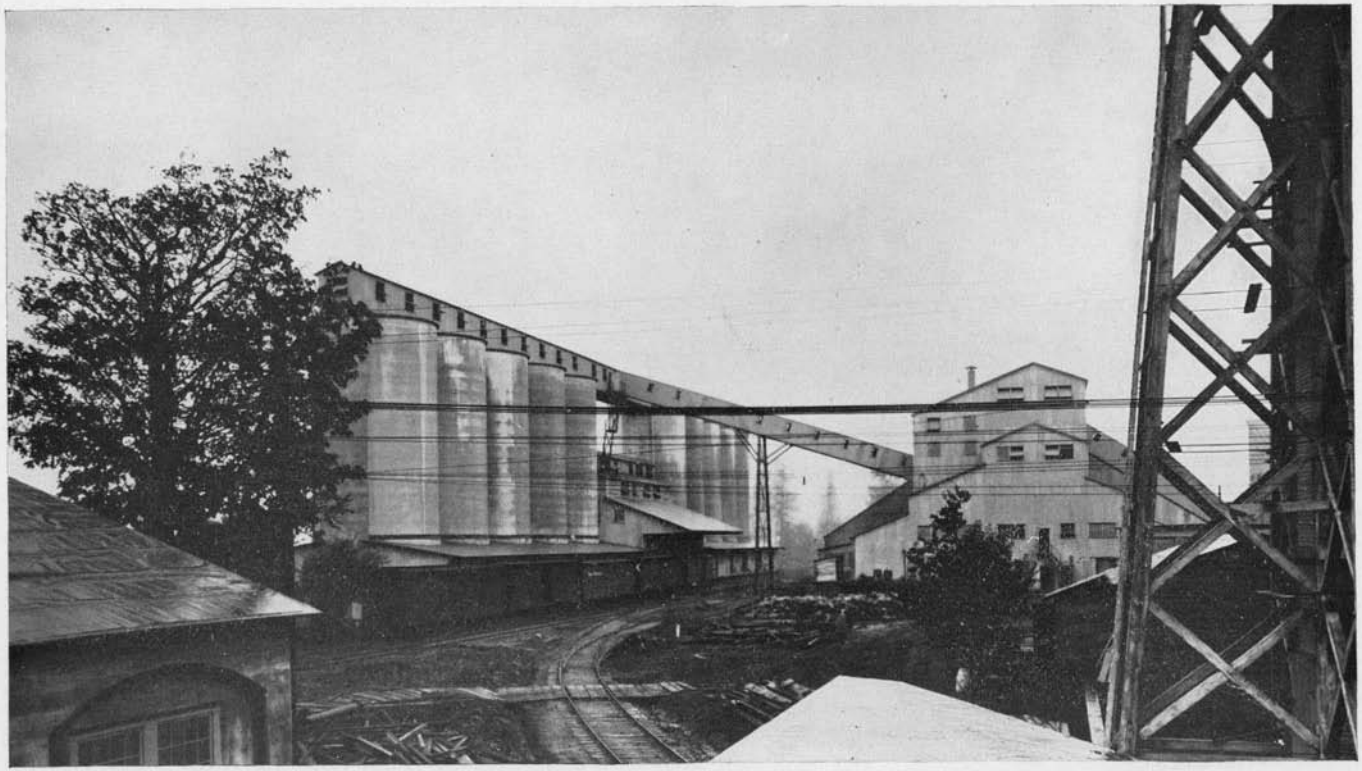
The above analysis shows this to be an especially pure limestone. There are but few deposits that carry as high a percentage of lime as this sample shows and with the proper material to mix with it a fine grade of Portland cement could be made.

FERRY COUNTY.

Ferry county lies just west of Stevens county, across the Columbia and kettle rivers. It has an average width east and west of about thirty miles and a length north and south of about seventy-five miles. The southern half of the county is entirely within the Colville Indian Reservation. In its general geology Ferry county is very similar to Stevens county. Metamorphic and igneous formations prevail, with some late sedimentaries. The metamorphic rocks include schists, quartzites, slates and greenstones. The igneous rocks include basalt, granite and rocks of this character. The sedimentaries are mostly lake beds of stratified tuffs and tufaceous shales. Clays are also found in places throughout the county.

Limestone.

Limestone bodies are found in a number of places in Ferry county. In most cases they are comparatively small, covering only limited areas. To the west of Orient in the Kettle river range of mountains, are probably the largest bodies in the county. These, however, are well up toward the summit of the range and are not easily reached. This limestone varies more or less in texture and ranges from fairly fine grained to extremely coarse grained. In color it is gray or white.



Cement Mill and Stock House of the Olympic Portland Cement Company at Bellingham.

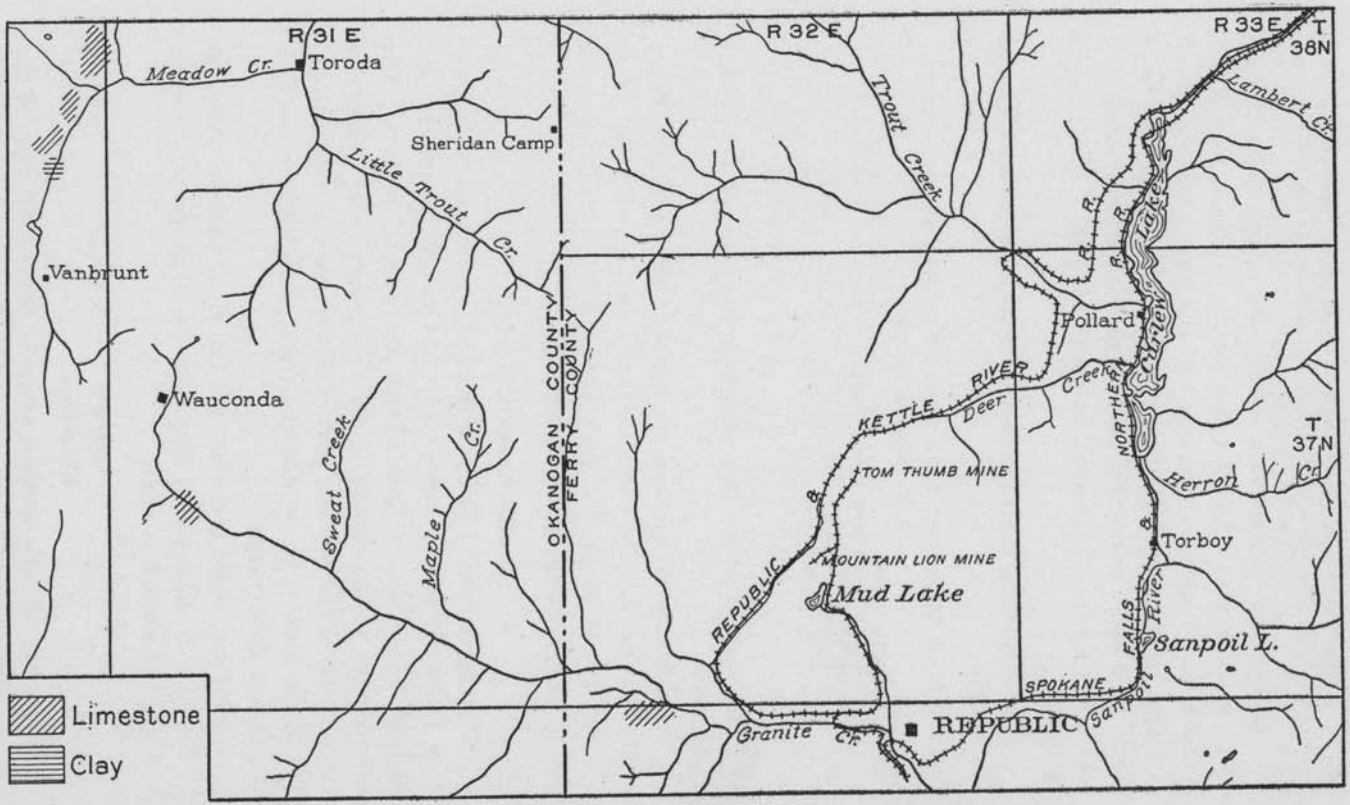


FIG. 4. Limestone and Clay deposits in the vicinity of Republic.

Laboratory Examination.—Only one sample from this locality was analyzed. In color this sample is almost pure white. It has a very coarse texture, many of the grains being as much as 5 mm. in diameter, while some of them are as much as twice that. It is easily pulverized and the powder, when treated with cold dilute hydrochloric acid, is dissolved with a fairly rapid effervescence.

The following analysis shows the chemical composition of this sample:

ANALYSIS OF LIMESTONE FROM WEST OF ORIENT, FERRY COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	4.65
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.99
Lime (CaO)	31.96
Magnesia (MgO)	19.31
Loss on ignition	43.54
Total	100.45

The analysis shows this sample to have a high percentage of magnesia.

Small bodies of limestone are found at other places in Ferry county, but no samples were analyzed from any of these. Most of these are so small that they are of little commercial value even if they are high grade limestones.

OKANOGAN COUNTY.

Okanogan county lies just west of Ferry county and extends westward to the summit of the Cascade Mountains and the high range east of Lake Chelan and parallel with it. The eastern part of the county in its topography and geology is very similar to the western part of Ferry county. About one-fifth of the county, the southeast corner, is included in the Colville Indian Reservation.

Limestone, shale and clay are found at various places in the county. In some places they occur in large quantities while in others the amount is small.

CHESAW.

Limestone.

Limestone is quite common around Chesaw, and some of the deposits cover a considerable area. The largest deposit in this

locality occurs on the east side of Myers creek and outcrops on the west face of Buckhorn Mountain. It begins in the bluffs east of Chesaw at an altitude of a little less than 3,500 feet and continues up the mountain to an altitude of 5,000 feet. The beds strike about north and south and dip to the east at an angle of about 35 degrees. These beds have a horizontal exposure here across the strike of a little more than a mile. The

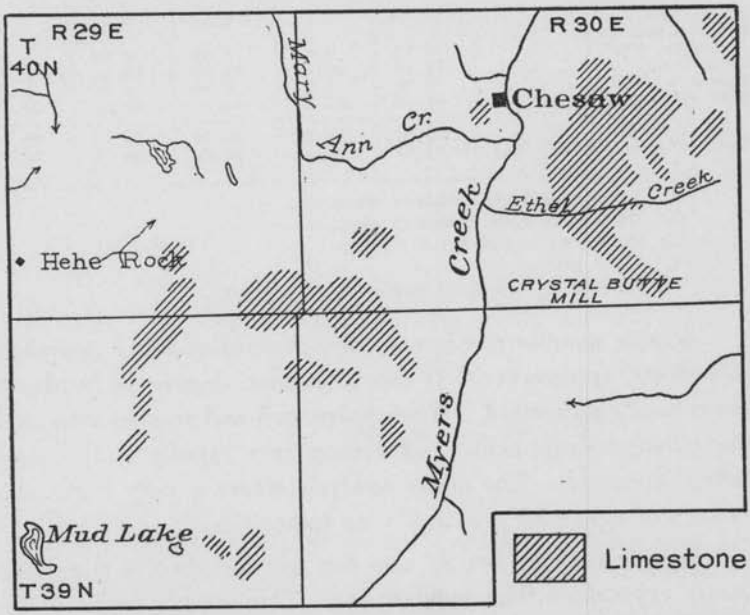


FIG. 5. Limestone deposits in the vicinity of Chesaw, Okanogan County.

beds on the whole appear to be fairly free from impurities. The bedding planes are fairly distinct in these deposits and the appearance throughout is quite uniform.

West and south of Chesaw are a number of smaller bodies of limestone. In places these deposits contain a considerable amount of impurities and are quite hard. The rock in the main is fine grained and ranges in color from light to dark gray.

Laboratory Examination.—A number of samples from different places in this locality were analyzed and the results are given below:

ANALYSES OF LIMESTONE FROM CHESAW, OKANOGAN COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.	III.	IV.	V.
Silica (SiO_2)	0.86	4.54	2.36	6.58	3.56
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.72	0.61	0.88	0.26	2.04
Lime (CaO)	54.10	50.69	51.89	49.90	52.56
Magnesia (MgO)	0.35	1.21	0.96	1.26	trace
Loss on ignition	42.50	42.85	43.21	41.50	40.88
Total	98.53	99.90	99.30	99.50	99.04
Calcium carbonate ($CaCO_3$)	96.61	90.51	92.66	89.17	93.75

I. Light gray from Buckhorn Mountain.
II. Dark gray from Buckhorn mountain.
III. Dark gray, southwest of Chesaw.
IV. Light gray.
V. Light gray, five miles southwest of Chesaw.

Sample number one is very fine grained and has somewhat of a flinty appearance. It has a medium degree of hardness and is easily pulverized. When pulverized and treated with cold dilute hydrochloric acid, it effervesces very rapidly and is completely dissolved. The above analysis shows a very high percentage of lime with practically no impurities.

Sample number two is also fine grained, but is more distinctly crystalline than number one. This sample varies somewhat in color but in the main it is a very dark gray with occasional thin seams of white running through it. This sample also shows well marked layers of light and dark materials in addition to the irregular seams of white. It is a trifle harder than the average limestone and would be a little harder to pulverize. The powder is light gray in color and when treated with cold dilute hydrochloric acid it effervesces very rapidly and is dissolved, with the exception of a small amount of black gritty material. The analysis shows a lower percentage of lime and a higher percentage of silica than number one. This, however, is a fairly good limestone.

Sample number three is very fine grained and dark colored. It has a very distinctly laminated structure, the individual layers being on an average about one-tenth of an inch in thickness. In some cases light and dark layers alternate, while in others the different layers have the same color. When pulverized it is very readily dissolved by cold dilute acids with the exception of a small amount of an almost black gritty sediment. The analysis shows this sample to have a little less silica and a little more lime than number two, and hence a little better grade of limestone.

Number four varies more or less in color, in some cases being very light and in others very dark, in fact almost black. It is very finely crystalline and fairly soft. When pulverized it is light gray in color and is readily dissolved by cold dilute hydrochloric acid, with the exception of a very small amount of dark colored residue. The analysis shows this sample to have the largest amount of silica and the smallest amount of lime of any of the samples analyzed from this locality.

There are not very many hard limestones being used in the manufacture of Portland cement that have less than 50 per cent of calcim oxide (CaO). This sample has practically that amount and under favorable conditions could be used.

Number five is finely crystalline and light gray in color. It is readily dissolved in cold dilute acids with rapid effervescence. The analysis shows this sample to have a fair percentage of lime and to be higher in alumina and iron than the other samples from this locality.

The above analyses show that any of these samples might be used in the manufacture of Portland cement. The material from Buckhorn mountain, east of Chesaw, however, would probably be the most satisfactory.

RIVERSIDE.

This is a small town on the Okanogan river about thirty miles north of its mouth. The stream at this point flows in a deep gorge with only a very narrow valley. The rocks in this locality are largely metamorphic.

Limestone.

Large deposits of limestone are found to the west and northwest of Riverside. These deposits cover many square miles in this locality and have a thickness in places at least of several hundred feet. They differ much in appearance, some of them being light colored, massive and very compact in texture. In other places the deposits are very shaley in structure, fine grained, and almost black in color. In some cases the deposits are very hard and flinty, while in others they are very soft.

Laboratory Examination.—The following analyses show the chemical composition of a number of samples from different parts of these deposits:

ANALYSES OF LIMESTONE FROM RIVERSIDE, OKANOGAN COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.	III.	IV.	V.	VI.	VII.
Silica (SiO_2)	2.24	12.00	1.76	2.16	10.44	5.02	12.86
Alumina and Iron (Al_2O_3, Fe_2O_3)	4.00	1.80	1.36	21.92	2.66	3.13	1.32
Lime (CaO)	49.05	45.91	52.42	30.22	1.78	32.07	31.25
Magnesia (MgO) ...	2.28	4.20	1.94	1.02	47.53	14.93	10.60
Loss on ignition.....	41.32	36.44	41.86	44.62	37.02	43.06	43.20
Total.....	98.89	100.35	99.34	99.94	99.43	98.21	99.23

I. Brownish blue, 1½ miles west of Riverside.
II. Black to blue, Scotch Creek Basin.
III. White crystalline, Scotch Creek Basin.
IV. Yellowish white, Johnson creek, 3 miles west of Riverside.
V. Black, 3 miles west of Riverside.
VI. White, west of Riverside. Sec. 25, T. 35 N., R. 25 E.
VII. Yellow, west of Riverside.

The above analyses show considerable variation in the composition of the materials around Riverside. Number one and three are the only samples that show a good percentage of lime. These are also quite free from magnesia and other detrimental impurities. Numbers 2, 5, 6, and 7 are all very high in silica and numbers 6 and 7 also contain large amounts of magnesia, while in 5 magnesia takes the place of practically all of the calcium. Numbers 6 and 7 are very hard and flinty in character, number 6, however, being distinctly crystalline.

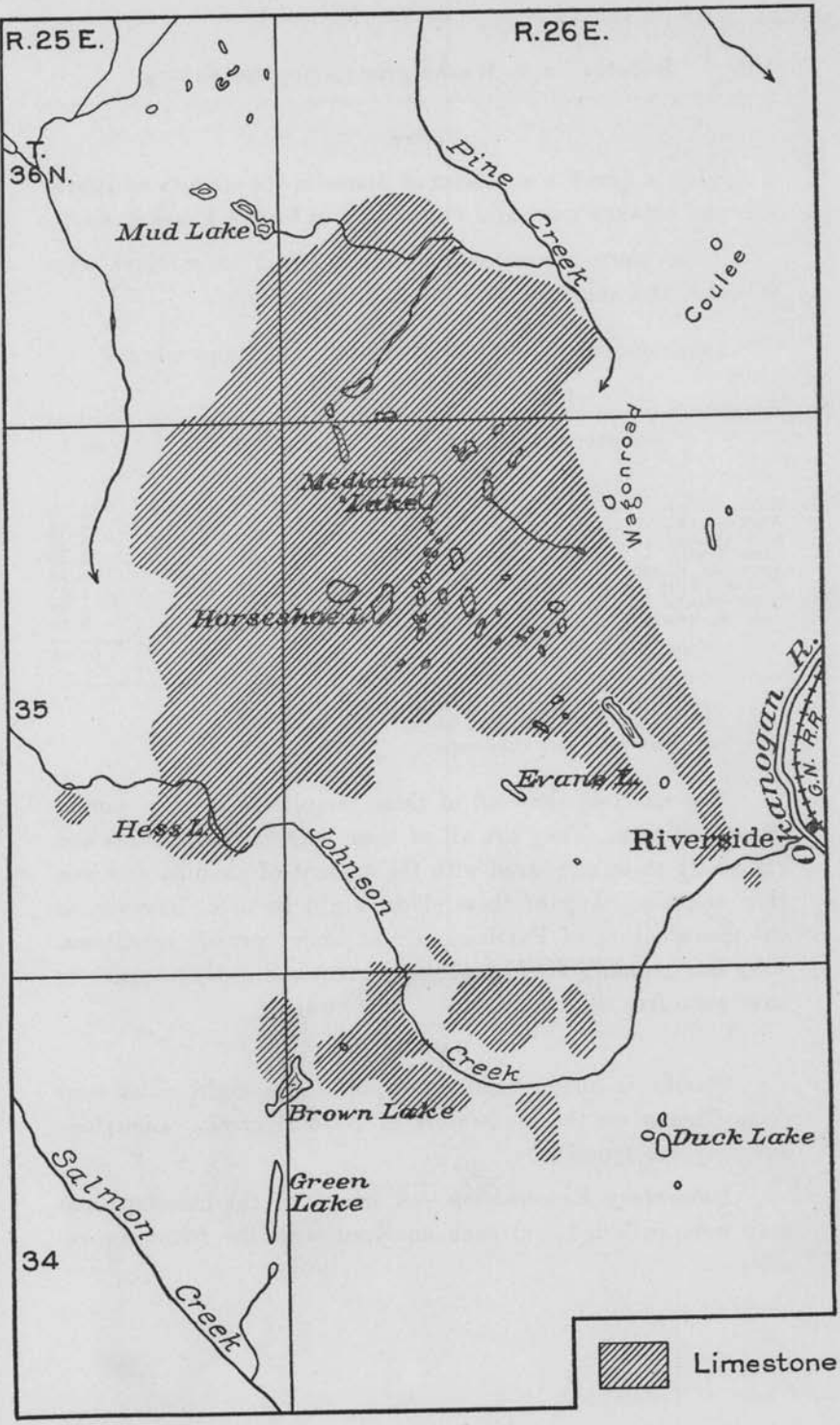


FIG. 6. Limestone deposits near Riverside, Okanogan County.

Clay.

Clay is found in a number of places in the vicinity of Riverside and between there and Conconully in Scotch Creek basin.

Laboratory Examination.—Samples of these clays were collected and analyzed with the following results:

ANALYSES OF CLAYS FROM RIVERSIDE, OKANOGAN COUNTY.

A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.	III.
Silica (SiO_2)	59.48	58.48	58.76
Alumina (Al_2O_3)	18.24	17.92	19.42
Iron (Fe_2O_3)	6.92	6.76	8.82
Lime (CaO)	2.95	5.26	6.48
Magnesia (MgO)	3.62	2.95	1.34
Potash (K_2O)	1.95	1.10	1.01
Soda (Na_2O)	2.21	1.98	0.66
Loss on ignition	5.26	4.26	3.10
Total	100.63	98.61	99.59

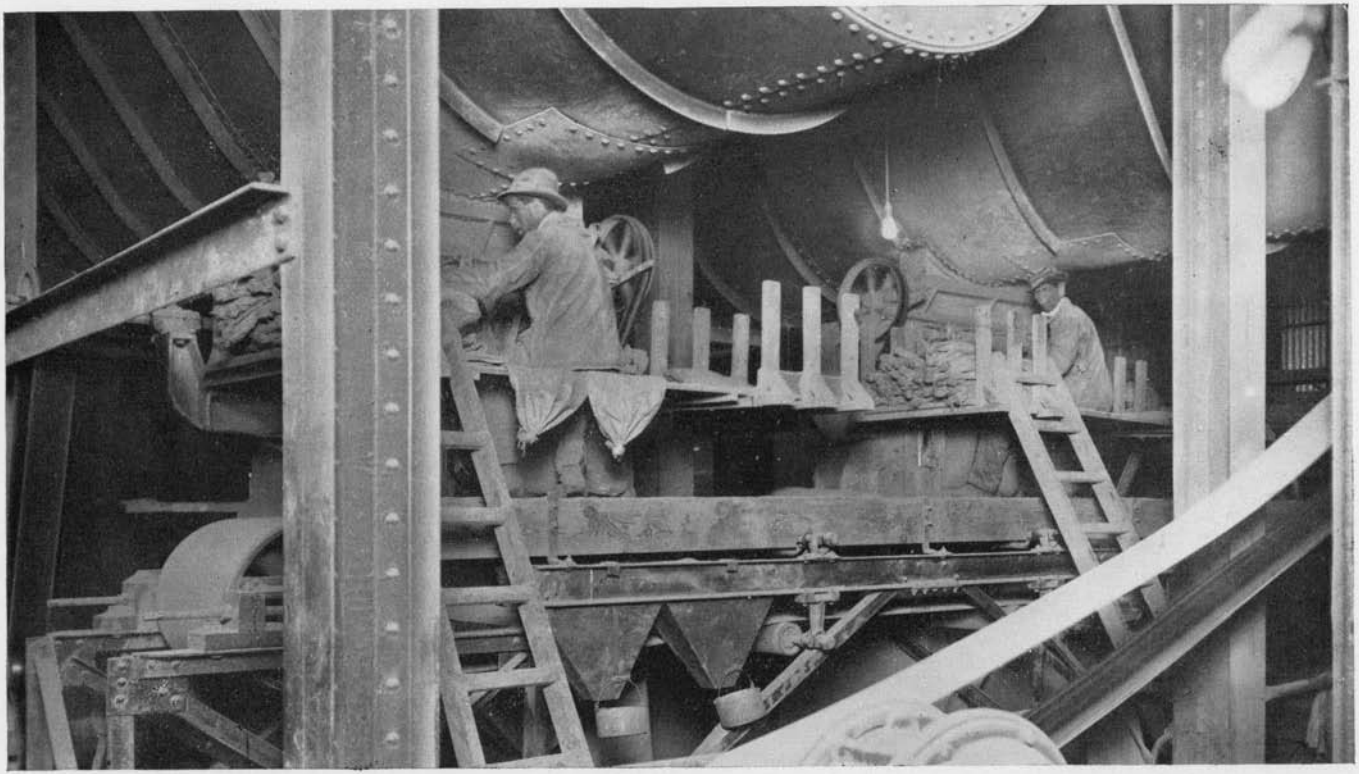
I. Bluish clay, Sec. 25, T. 35 N., R. 25 E.
II. Bluish clay, lake beds, Scotch Creek basin.
III. Clay from near Conconully.

The analyses show all of these samples to be very similar in composition. They are all of them a trifle low in silica and expecially so as compared with the amount of almuina and iron they contain. Any of these clays might be used, however, in the manufacture of Portland cement under proper conditions. Very fine grinding would probably be required as they appear to have some free silica.

HAVILLA.

Havilla is about eight miles south and eight miles west from Chesaw on the headwaters of Antoine creek. Limestone and clay are found here.

Laboratory Examination.—A sample of the limestone and clay were collected and each analyzed with the following results:



View in the Packing House of the Olympic Portland Cement Company at Bellingham.

ANALYSES OF LIMESTONE AND CLAY FROM HAVILLA, OKANOGAN COUNTY.

A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	57.68	1.80
Alumina (Al_2O_3)	15.74	0.60
Iron (Fe_2O_3)	8.14	
Lime (CaO)	5.77	54.62
Magnesia (MgO)	3.75	trace
Potash (K_2O)	1.32	.....
Soda (Na_2O)	1.41	.....
Loss on ignition	6.17	41.88
Total	99.98	98.90
Calcium carbonate ($CaCO_3$)	.....	97.53

I. Light yellow clay.
II. Crystalline limestone.

This clay is a very light yellow in color, fine grained and free from gritty substances. It slacks readily and when mixed with water becomes quite plastic. The above analysis shows it to have a little less than the average amount of silica and alumina, while the percentage of iron is higher than the normal. The ratio between the sum of the alumina and iron, however, is within the limits and this clay could probably be used satisfactorily in the manufacture of Portland cement.

The limestone found in this locality is bluish gray in color and finely crystalline. When pulverized it is dark gray and when treated with cold dilute hydrochloric acid it is practically all dissolved with very rapid effervescence. The above analysis shows this to be a very high grade limestone with a high percentage of calcium, practically free from impurities, and a geed stone from which to manufacture Portland cement.

WAUCONDA.

Wauconda is in the eastern part of Okanogan county on the headwaters of the west fork of Granite creek which empties into the Sanpoil river at Republic. A small body of limestone occurs about one mile south of Wauconda. Three or four miles north, on the headwaters of Meadow creek, are other small bodies of lime. In this same locality clay occurs also.

Laboratory Examination.—A sample of the limestone and the clay from north of Wauconda was analyzed and the results are given below:

ANALYSES OF LIMESTONE AND CLAY FROM WAUCONDA, OKANOGAN COUNTY.

A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	3.64	65.66
Alumina (Al_2O_3)	2.18	16.66
Iron (Fe_2O_3)		6.56
Lime (CaO)	49.36	3.10
Magnesia (MgO)	2.83	3.76
Alkalies (K_2O, Na_2O)	.....	undt.
Loss on ignition	39.28	1.40
Total	97.29	97 14
Calcium carbonate ($CaCO_3$)	88.15	.....

I. White crystalline limestone.
II. Light yellow clay.

This limestone is almost pure white in color, finely crystalline, and when treated with cold dilute hydrochloric acid, it is readily dissolved with rapid effervescence. The analysis shows this sample to be a little low in lime with some silica and magnesia. It is not an especially high grade lime but under very favorable conditions might perhaps be used for Portland cement.

The analysis of the clay shows it to be of good composition except that it does contain considerable magnesia. If it were used with a limestone practically free from magnesia, the amount is not so great as to prevent the use of this clay. It has a small amount of gritty material in it and this probably is very finely divided silica. On the whole this should be a very satisfactory clay to use in the manufacture of Portland cement.

CHELAN COUNTY.

Chelan county lies on the eastern slope of the Cascade Mountains just west of Okanogan and Douglas counties. One of the most noted topographic features of the county is the long narrow gorge, extending northwest and southeast almost

across the county, in which Lake Chelan is situated. In the main the county consists of high mountains and long narrow valleys.

WENATCHEE.

Limestone.

About five miles north from Wenatchee is a deposit of limestone. This is in the N½ of the NE¼ of the SW¼ of section 10, township 23 north, range 20 east. This limestone is white to gray in color and finely crystalline. The deposit is massive, with little signs of stratification. Considerable lime has been taken from this deposit, the workings showing an exposure of lime about twelve feet deep and extending for some distance around the side hill. The deposit is back from the Columbia river and about 100 feet above the flat which extends along the river at this place.

A kiln is in operation here during part of each year, the capacity of which is about 60 barrels a day. Across a small gulch on the same property is another outcrop of apparently the same limestone, but it has not as yet been opened up. It is difficult to tell just the extent of these limestones as the deposit appears to dip into the side hill. The indications, however, are that they are not very extensive.

Laboratory Examination.—This limestone is not very hard and can be easily pulverized. When powdered it is practically white in color and is readily dissolved in cold dilute hydrochloric acid.

The following analysis shows the chemical composition of the limestone from this locality:

ANALYSIS OF LIMESTONE FROM WENATCHEE, CHELAN COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	0.38
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.21
Lime (CaO)	55.26
Magnesia (MgO)	none
Loss on ignition	43.98
Total	99.83
Calcium carbonate ($CaCO_3$)	98.68

The above analysis shows that this is a very high grade limestone.

Clay.

Clay is quite common in the Wenatchee valley and while no analyses have been made of it the indications are that it might be used to mix with this limestone in the manufacture of Portland cement. The clay in the valley is usually light yellow in color and fairly free from gritty particles of any kind.

CHELAN.

Limestone.

Limestone occurs on the shores of Lake Chelan from eighteen to twenty miles above the town of Chelan. The deposits are in section 29, township 29 north, range 21 east, and sections 13 and 14, township 29 north, range 20 east. Two of these deposits are on the south shore of the lake while the other is on the north side.

The limestone in section 29 is white in color and finely crystalline. It is not very hard and would pulverize easily. There appears to be a large body of limestone at this point as it outcrops in places to a height of as much as 900 feet above the lake. The deposit is badly shattered and contains dikes of green igneous material cutting through it. The limestone appears to be in contact with igneous rocks and to lie on them. The limestone at this point has been used for the burning of lime and it is claimed that the product was of good quality.

The limestone in section 14 is on the south shore of the lake and outcrops at the water's edge. Some stripping has been done and the limestone exposed about 120 feet up the slope and about 30 or 40 feet horizontally along the side of the hill. A kiln has been located here and some lime burned. The deposit is tratified and has a dip of about 60 degrees to the west. The limestone is cut by a dike of dark green igneous material and appears to rest on igneous rock. It is almost white in color and finely crystalline. When pulverized and treated with cold dilute hydrochloric acid it dissolves rapidly the whole of it going into solution.

The deposit in section 13 is on the north side of the lake at the water's edge, and is exposed a distance of at least 350 feet up the slope of the hill. Some work has been done here and a face about 30 feet high and about 50 wide has been exposed. A good lime kiln has been installed at this point and some lime burned. The deposit is distinctly stratified and apparently very

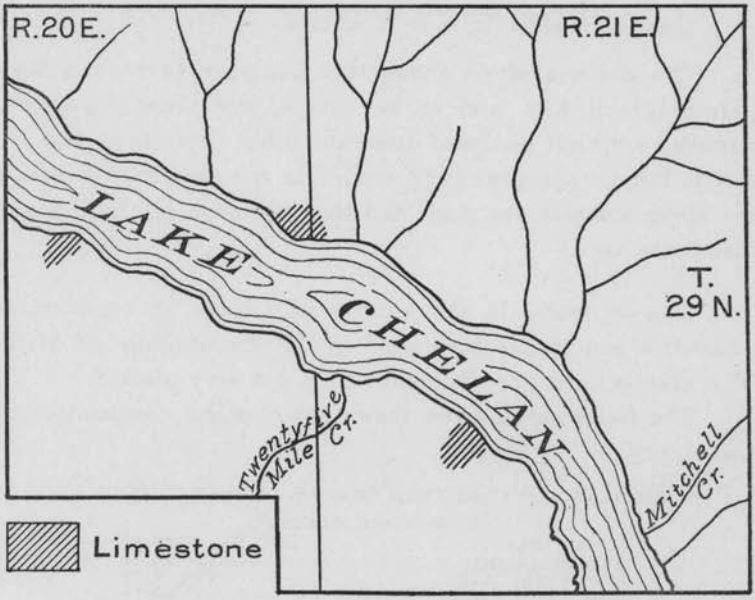


FIG. 7. Limestone deposits on the shores of Lake Chelan.

uniform throughout. This deposit varies somewhat in color, in places being almost pure white, while in others it is a very light bluish gray.

Laboratory Examination.—The samples from this locality are distinctly crystalline, the individual crystals being in the main from 1 to 2 mm. in diameter. This stone is not very hard and pulverizes easily.

The following analysis shows the chemical composition of this limestone:

ANALYSIS OF LIMESTONE FROM LAKE CHELAN, CHELAN COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	2.40
Alumina and Iron (Al_2O_3, Fe_2O_3)	trace
Lime (CaO)	53.28
Magnesia (MgO)	0.65
Loss on ignition	43.26
Total	99.59
Calcium carbonate ($CaCO_3$)	95.14

Limestone from Sec. 13, T. 29 N., R. 20 E.

The above analysis shows this limestone to have a high percentage of lime and to be almost free from impurities. Samples were not analyzed from the other deposits in this locality, but they appear very similar to the sample from which the above analysis was made and they are probably high grade limestones also.

Clay.

Clay is found in the vicinity of Chelan in considerable quantities and it has been used in the manufacture of brick. This clay is light gray in color and is not very plastic.

The following analysis shows the chemical composition of this clay:*

ANALYSIS OF CLAY FROM CHELAN, CHELAN COUNTY.

W. R. BLOOR, Analyst.

Silica (SiO_2)	59.84
Alumina (Al_2O_3)	16.40
Iron (Fe_2O_3)	4.10
Lime (CaO)	5.84
Magnesia (MgO)	0.36
Potash (K_2O)	1.62
Soda (Na_2O)	2.84
Titanium (TiO_2)	1.20
Other constituents	1.32
Moisture (H_2O)	0.74
Loss on ignition	5.51
Total	99.77
Total fluxes	17.28

The above analysis shows this clay to be a trifle low in silica and alumina. The ratio between the silica and the sum of the alumina and iron, however, is a very good one. The amount of fluxing substances is great enough so that this clay will fuse at low temperatures. The analysis shows this clay to

*Shedd, The Clays of the State of Washington, Their Geology, Mineralogy, and Technology, p. 235.

have a good composition and well suited to be used in the manufacture of Portland cement.

SPOKANE COUNTY.

No limestone deposits of any importance have been found in Spokane county, but large deposits of clay are found in various parts of the county. In places these are being extensively used in the manufacture of various clay products, but are not being used in the manufacture of Portland cement.

International Portland Cement Company.—In spite of the absence of limestone one plant for the manufacture of Portland cement has been built, and is in operation, in the county. The materials used at this plant are obtained at Pend Oreille lake in Idaho.

The following analyses, furnished by H. W. Wood, chief engineer of the International Portland Cement Company, show the composition of these materials:

ANALYSES OF LIMESTONE AND SHALE FROM PEND OREILLE LAKE, IDAHO.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	2.78	67.80
Alumina (Al_2O_3)	1.00	15.13
Iron (Fe_2O_3)		4.61
Lime (CaO)	52.84	1.19
Magnesia (MgO)	1.13	1.80
Loss on ignition	42.24	8.02
Total	99.99	98.55
Calcium carbonate ($CaCO_3$)	94.35	.....

I. Limestone.
II. Shale.

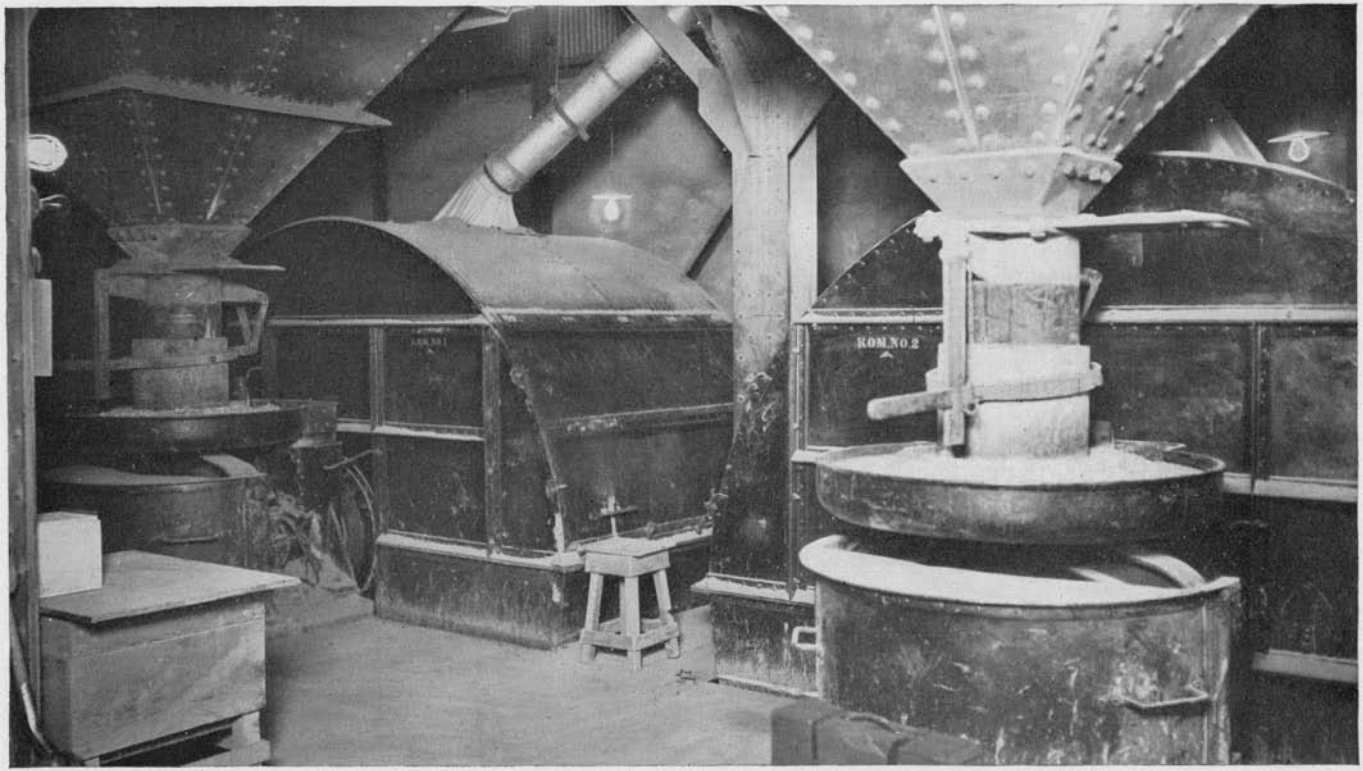
Description of the Plant.—The plant of the International Portland Cement Company is located at Irvin Station, Washington, nine miles east of Spokane. The materials used at this plant are limestone and shale, and are obtained from Lake Pend Oreille, Idaho, about fifty miles from the plant, where the crushing plant is located.

The limestone is crushed by means of one No. 8 and two No. 6 Gyratory crushers and the shale is crushed by one No. 6 crusher. The crushed rock is then delivered into large storage

bins having a capacity of about 3,000 tons. These bins are located right at the water's edge and are sufficiently high to discharge directly into cars on transfer barges, the transfer barges having a capacity of six 50-ton cars each. After the cars are loaded the barges are towed across the lake, a distance of about six miles, to Bayview, at which point the cars are transferred to the railroad and taken to the plant at Irvin Station. A storage capacity is provided at the plant sufficient to hold a month's supply of limestone, shale and coal.

The raw material arriving at the plant is discharged from hopper bottom cars under a three-track storage trestle, two tracks for limestone and one for shale. Below the raw material storage are provided two tunnels, one for limestone and one for shale. In these tunnels are belt conveyors, receiving the materials from gates in the roof of the tunnel, which deliver their materials to the ball mills for limestone and hammer mills for shale. These machines are the preliminary grinding machines. The material passing through the preliminary machines is then delivered to two dryers, each 7 feet in diameter and 70 feet long, one dryer for limestone and one for shale. Discharging from the dryers the limestone and shale are lifted up separately by means of elevators and distributed by conveyors over large compartment bins with a total capacity of 24 hours. Below the bin is arranged an electric travelling hopper weigh scale car. The materials in the compartment tanks of which there are 11 for limestone and 11 for shale, are sampled and are drawn direct into the weighing car, where the correct mixture is made by weight. It is then conveyed direct to the bins serving the Fuller mills in the raw grinding department.

This department is equipped with three 54 inch Fuller Dreadnaught mills, each driven by means of a 150 H. P. vertical motor. There is located above these pulverizers a 10-ton traveling crane for facilitating the making of repairs when necessary for both the pulverizers and the vertical motors. This crane is also used in erecting the machinery. The finely pulverized raw materials discharging from the Fuller pulverizer



Interior of the Cement Mill of the Olympic Portland Cement Company at Bellingham.

mills are then taken direct to the raw material stock bin above the kilns, this bin having a capacity of 24 hours. The installation consists of two 8½x160 foot rotary kilns, provision being made for an additional kiln. The clinker discharging from the kilns drops directly into rotary coolers, one cooler for each kiln. These coolers are 7 feet in diameter and 70 feet long, the coolers being located below the burning floor. The air being drawn either by the draught of the kiln stack or by means of separate stack, which is arranged directly alongside of the kiln hood, the stack having a damper to control the amount of air passing through the coolers. In other words, the hot air coming from the coolers can go direct into the kilns, or out through the separate stack into the atmosphere. Below each cooler is located an automatic weighing machine for furnishing information as to the daily operation of the kilns.

The clinker leaving the coolers is carried direct to a covered clinker storage. There is a tunnel located in the floor and the elevators and conveyors are so arranged that the clinker may be taken direct from the coolers or from the storage to the clinker mill.

The clinker grinding department is provided with one set of 30x18 inch Lehigh crushing rolls, which are used for breaking down any large lumps of clinker that may come from the coolers. These rolls are set to pass 1 inch material. The clinker passing these rolls is delivered to a large bin above the pulverizers. The installation of pulverizers consists of four Fuller Dreadnaught mills, each driven by one 150 H. P. motor. Above these pulverizers and motors there is an installation of a 10-ton traveling crane, the same as in the raw grinding department, to facilitate the making of repairs when necessary. The finely pulverized cement being discharged from the Fuller mills is delivered by means of a short bridge over to the stock house.

The stock house is divided into 21 bins, each having a capacity of about 2400 barrels. The bins are arranged in three rows, 7 bins in each row. Each row of bins is provided with a tunnel, running the entire length of the stock house. The bot-

tom of the bins is hoppered so that the cement in each and every bin in the stock house can be drawn off directly into the conveyors in the tunnels, these conveyors being sufficiently low so that the cement will flow by gravity.

Being carried directly to the packing house the cement is lifted up and delivered to bins over the packing machines. The packing house is provided with two of the latest type Bates valve packing machines on the second floor, where the bags, being packed, are dropped through the floor into a chute leading direct to the cars, thereby eliminating trucking and handling.

Pulverized coal is used for burning in the kilns. The coal is brought to the plant and stored under a double track trestle, provided with a tunnel which runs the entire length of the trestle. The coal is drawn from the storage on to the belt conveyor in the tunnel and delivered direct to a set of 18x24 inch crushing rolls, located in the coal mill, where the coal is reduced to pass through 1 inch ring. This crushed coal is then lifted up and passes through a weighing machine and from there directly through a 4½x30 foot indirect fired rotary dryer. From the dryer the coal is then delivered to a bin located above two 42 inch Fuller mills, each driven by means of a 75 H. P. vertical motor. After being pulverized the coal is elevated and conveyed through a short bridge to the cylindrical storage bin located in front of the kiln, each kiln being provided with separate storage tanks of about 14 hours' capacity, so that the coal mill will not have to operate at night. In the front of each kiln there is located a motor driven blower for furnishing the blast for injecting the coal into the kilns, the pressure of the blast being 7 ounces.

The power of the plant is purchased from one of the large hydro-electric developments, for which this section is famous the world over. It is delivered to the plant over duplicate cables at 60,000 volts. The plant is provided with a transformer house where the current is stepped down from 60,000 to 440 volts, 3 phase, 60 cycle. The transformer station is provided

with a suitable switchboard with distributing panels for controlling each and every department of the plant.

This plant is also provided with a machine shop and blacksmith shop for making the necessary repairs and store house for carrying the supplies required for operating the mill. It is the latest and most up-to-date plant put into commission in the United States during the year 1912, and has a capacity of 1600 barrels per day. The most modern and improved machinery has been installed. The location of the plant affords excellent shipping facilities into Spokane and the entire northwestern section of the United States.

PEND OREILLE COUNTY.

This county is in the extreme northeastern corner of Washington. The main stream in the drainage of the county is the Pend Oreille river, which enters the county near its southeastern corner, flows westward for about eight miles and then northward across the county. Smaller mountain streams tributary to the Pend Oreille are numerous, some of the more prominent in the east side being Leclare creek which flows almost due south and Sullivan and Slate creeks, which flow west. On the west side are Calispel creek, which flows northward, Lost, Muddy, Ione, and Flume creeks, all of which flow in an eastward direction. These mountain streams, in many cases at least, are very valuable for generating power as they have high gradients.

TOPOGRAPHY.

The southern part of the county consists largely of low rolling hills, while the central and northern parts comprise high hills and stream valleys. The most prominent topographic feature in the county is the valley along the Pend Oreille river. In places this valley has a width of several miles, but in others it is very narrow. In places benches a few feet above the river extend back from it for considerable distances, but in others the bluffs rise abruptly from it. In some cases the tendency is for the bluffs to occur in benches ranging in height from 100 to 250 feet above the river. Back from the river and above these

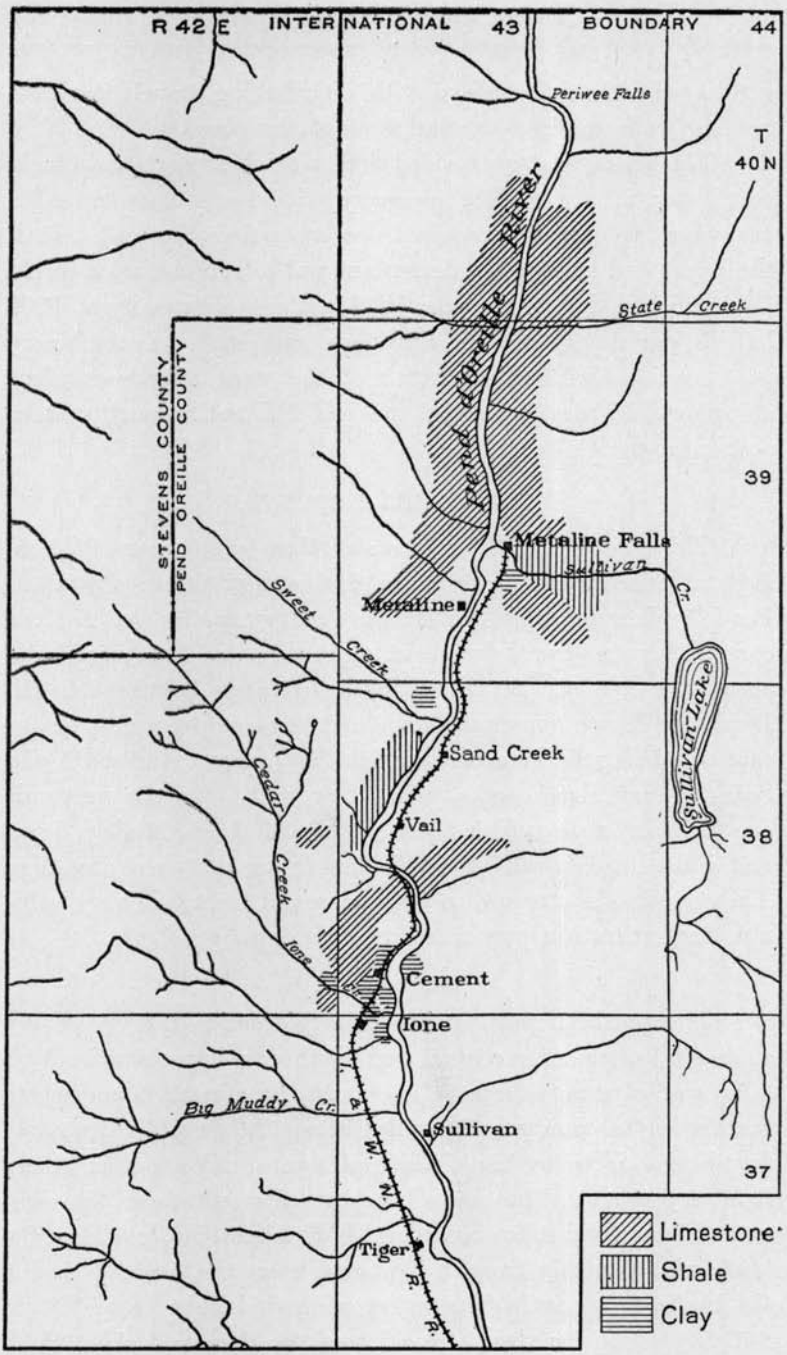


FIG. 8. Map of a part of Pend Oreille County, showing the distribution of Limestone, Shale and Clay deposits.

benches rise steep timber-covered mountains, the highest of which attain altitudes of 6,000 to 7,000 feet above sea level.

GEOLOGY.

The geology of Pend Oreille county in its main features is similar to that of Stevens county which lies just west of it. The rocks over a considerable part of the county are more or less metamorphosed sedimentaries and consist mostly of shales and limestones, the latter in many cases being dolomite. Igneous rocks which show practically no signs of metamorphism do occur, however, in places in the county. No fossils were found in connection with any of the formations and their age is not known. Around Metaline Falls the beds appear to have a more or less north and south strike, with a fairly constant westward dip.

Large deposits of alluvial clays are found in many places along the Pend Oreille river. These are usually bluish, grayish, or yellowish in color, fine grained, and free from gritty materials.

Almost the whole of Pend Oreille county east of the Pend Oreille river is within the Kaniksu national forest reserve.

CEMENT.

This is a very small town on the line of the Idaho and Washington Northern Railway, about 40 miles north of Newport and about one mile north of Ione, which is the principal town in this part of the valley. The Pend Oreille river is also navigable from Newport to Cement so that there are very good transportation facilities to and from this point.

Limestone, clay, and shale deposits occur adjacent to the town and considerable work was done here at one time and a little natural hydraulic cement manufactured at this place in February and March of 1904. The deposits here were located in January, 1901, by F. G. Jordan.

Field Examination.—The old cement plant and the town of Cement are on the west side of the Pend Orielle river, just at the upper end of Box canyon. A small flat occurs here which has

been formed by material being deposited from the river and back of this hills rise abruptly reaching an altitude of 1,200 feet above the stream or about 3,150 feet above sea level. Practically the whole of this 1,200 feet is limestone. The deposits vary somewhat in appearance in different places. In some places they show fairly well marked stratification. Much of the limestone is quite dark in color before weathering, but on exposure it becomes lighter colored. Much of the deposit is badly shattered and broken into small pieces. A quarry has been opened in the north bluff and a road built to the foot of the hill. The limestone here varies but little in appearance and would seem to be quite uniform, not only in texture, but also in composition. It is very fine grained and on fresh unweathered surfaces is very dark, slightly bluish, in color.

The quantity of limestone in these deposits is very large. They extend along the river for more than a mile and rise above it for at least 1,200 feet.

Shales were found at but one place in connection with the limestones in this immediate vicinity. They occur between the north and south bluffs about 500 feet above the river. A small opening has been made at one place and a face about 30 feet wide and 6 feet high exposed. Loose shale was found on the surface for a considerable distance which might indicate a large body of this material. Nothing definite, however, could be told in regard to the extent of the deposits. Shales are very common along the Pend Oreille river below Box canyon and occur in very large quantities.

The flat which occurs along the river at this place contains the clay deposits that were to have been used by the Pacific Coast Portland Cement Company. This flat extends along the river for more than half a mile and in width is from a few to as much as forty rods. Considerable prospecting has been done on this flat by digging test pits at various places and to various depths, in some cases 50 feet or more and it is claimed that a large body of clay occurs here. Clay has also been exposed in

a bank, a little above this flat, at one or two places where the Idaho and Washington Northern Railway has cut through it. In appearance this clay is very different from that which occurs on the flat. It is darker colored and occurs in well defined layers.

Clays are also found on Cedar creek at the place where the dam has been built across it. This clay occurs in a finely stratified deposit and is underlayed by sand and gravel. The clay when wet is dark gray in color and light gray when dry. It occurs in the hillside, about 15 feet in thickness, is exposed, and it outcrops along the bank for more than 100 feet.

Limestone.

Laboratory Examination.—These deposits of limestone contain, in places at least, more or less siliceous material and it is claimed that good natural cement material occurs here. One sample of this material was collected and analyzed with the following results:

ANALYSIS OF LIMESTONE FROM CEMENT, PEND OREILLE COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	17.04
Alumina (Al_2O_3)	7.48
Iron (Fe_2O_3)	2.60
Lime (CaO)	40.47
Magnesia (MgO)	3.91
Loss on ignition	29.02
Total	100.52

The above chemical analysis shows this sample to approach closely the composition of some of the limestones that are being used in the United States as materials from which to manufacture natural hydraulic cement. The main difference is in the amount of lime, which is high, and the amount of loss on ignition, which is low. This stone is very fine grained, dark and almost black in color.

The following chemical analyses were furnished me by Mr. F. G. Jordan, and are all of what he terms the natural hydraulic cement rock:

ANALYSES OF LIMESTONE FROM CEMENT, PEND OREILLE COUNTY.

Silica (SiO_2)	11.40	8.00	15.60	10.60	11.30
Alumina and Iron (Al_2O_3, Fe_2O_3)	1.06	1.10	2.30	2.10	1.70
Lime (CaO)	48.75	49.71	45.60	47.62	45.97
Magnesia (MgO)	none	trace	trace	trace	trace
Silica (SiO_2)	11.40	8.80	26.04	16.60	19.40
Alumina and Iron (Al_2O_3, Fe_2O_3)	1.80	2.00	14.54	2.92	7.60
Lime (CaO)	40.30	47.77	29.34	38.28	34.40
Magnesia (MgO)	trace	trace	3.32	4.40	trace

One thing that is very noticeable in all but two of these analyses is the very small amount of iron and alumina shown. The percentage of lime, on the other hand, is high in all but three of them.

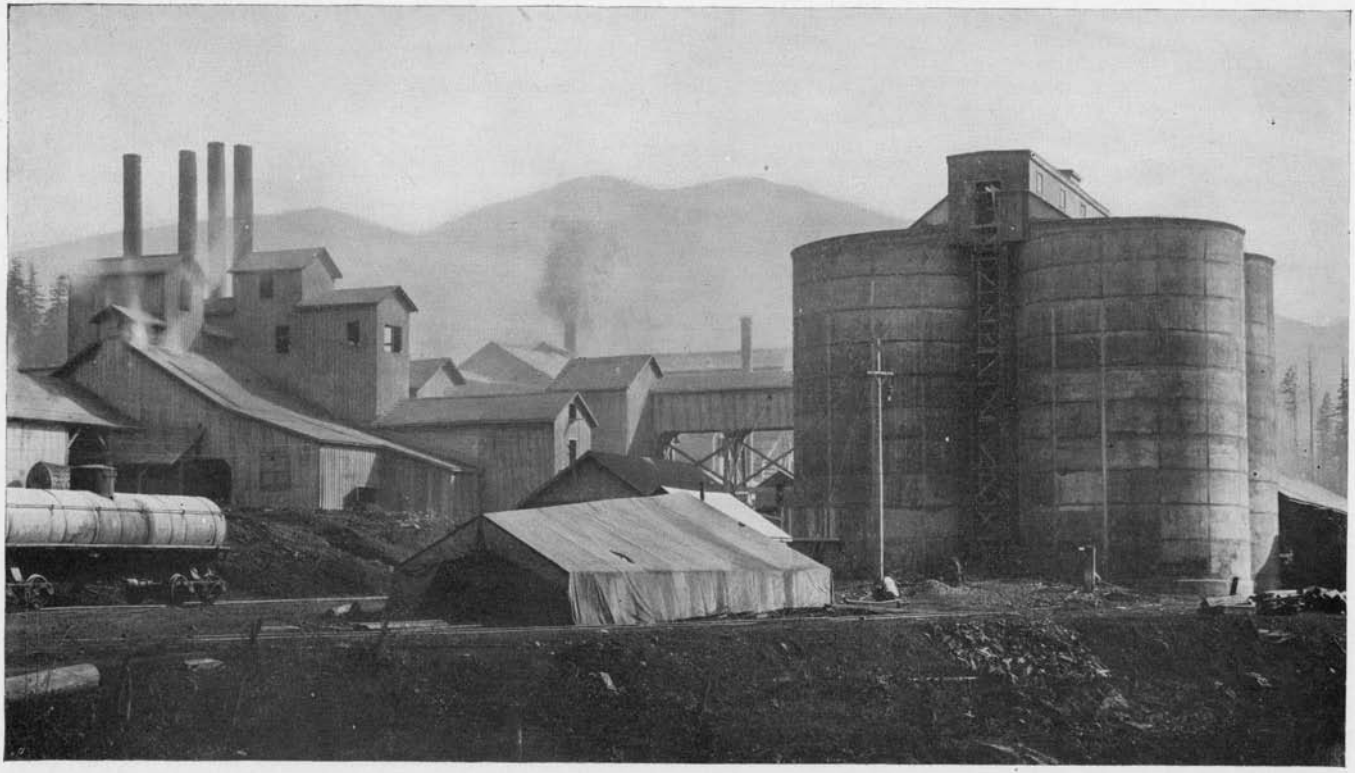
This stone when pulverized is light gray in color, effervesces rapidly in dilute hydrochloric acid and dissolves leaving a dark colored residue.

Two other samples of this limestone were collected a little lower down the hill and a short distance from where the first was obtained. Each of these were analyzed and the results are given below:

ANALYSIS OF LIMESTONE FROM CEMENT, PEND OREILLE COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	6.92	3.10
Alumina and Iron (Al_2O_3, Fe_2O_3)	2.92	1.68
Lime (CaO)	48.65	51.12
Magnesia (MgO)	1.24	0.96
Loss on ignition	39.34	42.90
Total	99.07	99.76

The main difference in the two samples is that number one is weathered, while number two appears fresh and unweathered. These samples were fine grained and number one was lighter colored than the one from higher up the hill. It had changed



General View of the Plant of the Superior Portland Cement Company at Concrete.

more from exposure to atmospheric agencies and this may have been the cause for this to a very great extent at least.

Sample number one effervesces very rapidly in dilute hydrochloric acid and dissolves almost completely. The slight residue that is left has a reddish brown color.

In composition these samples are very different from the first one given. They each of them contain much less silica, iron and alumina and magnesia, while they both contain considerable more lime. Number two, especially, is a very good grade of limestone.

A composite sample from the center bluff was also analyzed. This sample consisted of a large number of small samples taken at intervals along the face of the bluff. The small samples were then mixed and a sample for analysis taken from this.

The following analysis shows the chemical composition of this sample:

ANALYSIS OF LIMESTONE FROM CEMENT, PEND OREILLE COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	3.60
Alumina and Iron (Al_2O_3, Fe_2O_3)	4.12
Lime CaO)	49.28
Magnesia (MgO)	trace
Loss on ignition	41.94
Total	98.94

This sample differs little in composition from the others. All of the analyses so far given show only small amounts of magnesia, which is an essential if the limestone is to be used in the manufacture of Portland cement.

According to analyses furnished by Mr. F. G. Jordan, there is one place where this limestone carries a high percentage of magnesia. The following analyses were furnished by him and are given here to show the amount of this substance found at this place:

ANALYSES OF MAGNESIAN LIMESTONE FROM PEND OREILLE COUNTY.

Silica (SiO_2)	5.00	trace	5.00	4.60
Alumina and Iron (Al_2O_3, Fe_2O_3)	3.80	2.50	4.90	1.30
Lime (CaO)	31.05	30.25	30.97	30.52
Magnesia (MgO)	16.54	17.12	15.67	18.10

According to Mr. Jordan, these magnesian limestones cover only a small area near the southern part of the south bluff.

Shale.

The shale which occurs in connection with the limestone deposits at Cement is very light gray in color, finely laminated, and to the unaided eye it is homogeneous and compact, but under a strong hand lens it appears very finely granular. When viewed under a strong glass it has more or less of a mottled appearance, some parts being darker-colored than others. Over the surface are particles of considerable size that are reddish brown under the glass. When pulverized this shale is much lighter in color than it is in the mass.

The following chemical analysis shows the composition of this material:

ANALYSIS OF SHALE FROM CEMENT, PEND OREILLE COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	54.68
Alumina (Al_2O_3)	22.15
Iron (Fe_2O_3)	9.09
Lime (CaO)	2.03
Magnesia (MgO)	2.52
Potash (K_2O)	1.75
Soda (Na_2O)	1.42
Loss on ignition	4.78
Total	98.42

The above analysis shows this shale to be a little below the average in silica of those that are being used in the manufacture of Portland cement (see page —), and the amount of alumina and iron are each of them a little above the average. The ratio between the silica and alumina is 2.47:1, which is low, and the percentage of iron being high would make it still worse. The amount of lime in this shale is very small and the percentage of magnesia is easily within the allowable limit. If some highly siliceous material could be found and a small amount of it mixed with this shale the results would probably be very satisfactory and furnish a first class material to mix with limestone in the manufacture of Portland cement.

Clay.

The clays which occure at Cement vary more or less in color. Those in the flat along the river are yellow or buff col-

ored on the surface, but after a given depth is reached, they are blue, while those up Cedar creek have a slightly bluish tinge. All of them are fine grained, plastic clays which slack readily in water. They contain some fine particles of gritty material, however, which is probably largely silica.

The following analyses show the chemical composition of these clays:

ANALYSES OF CLAYS FROM CEMENT, PEND OREILLE COUNTY.

CONSTITUENTS.	I.	II.	III.	IV.
Silica (SiO_2)	61.58	63.28	62.96	64.10
Alumina (Al_2O_3)	20.29	18.64	18.82	} 22.30
Iron (Fe_2O_3)	5.95	7.52	7.35	}
Lime (CaO)	1.34	1.97	2.00	1.69
Magnesia (MgO)	2.30	3.16	3.62	trace
Potash (K_2O)	} 2.01 {	1.70	undt.	.....
Soda (Na_2O)	}	1.07	undt.	.....
Moisture (H_2O)	1.94	.....	.....	.....
Loss on ignition	4.14	2.26	3.00	.....
Total	99.55	99.60	97.75	.....

I. Clay from flat along river, W. R. Bloor, analyst.
II. Clay from railway cut, A. A. Hammer, analyst.
III. Massive yellow clay, A. A. Hammer, analyst.
IV. Bulletin 285, U. S. Geological Survey, Washington D. C., p. 382.

The above analyses show these clays to be well suited to mix with limestone in the manufacture of Portland cement. The ratio between the silica and almuina is good, the amount of iron and alkalies is sufficient to cause them to fuse at fairly low temperatures, and yet the amount of iron is not great enough to produce an especially dark colored cement.

Number one is completely fused at about 1,290° C.*

In studying the clays of Washington, a microscopic examination of samples of No. 1 was made with the following results:†

"The microscope shows this clay to consist of a mass of grains, most of which are very sharp cornered and irregular in outline. A few of these grains are as much as .1 of a mm. in

*Shedd, Clays of the State of Washington, Their Geology, Mineralogy, and Technology, p. 214.

†Shedd, Clays of the State of Washington, Their Geology, Mineralogy and Technology, p. 215.

diameter, a considerable number of them are .05 of a mm. in diameter, but by far the larger part are .005 of a mm. and less in diameter. The larger grains are colored brownish and greenish, while the smaller ones are colorless and clear. Individuals of quartz, feldspar, mica, calcite, and zircon were observed in the sample examined."

The following analyses of this clay were furnished by Mr. F. G. Jordan:

ANALYSES OF CLAY FROM CEMENT, PEND OREILLE COUNTY.

CONSTITUENTS.	I.	II.	III.	IV.
Silica (SiO_2)	57.53	68.33	66.32	71.74
Alumina and Iron (Al_2O_3, Fe_2O_3)	28.37	22.71	24.48	20.56
Lime (CaO)	1.88	1.88	1.96	1.97
Magnesia (MgO)	4.50	2.55	2.68	2.23

CONSTITUENTS.	V.	VI.	VII.	VIII.	IX.
Silica (SiO_2)	68.94	76.00	76.52	70.90	77.95
Alumina and Iron (Al_2O_3, Fe_2O_3)	21.64	17.02	16.38	20.04	15.53
Lime (CaO)	1.36	1.46	1.36	1.30	1.61
Magnesia (MgO)	2.24	1.66	1.77	1.99	1.26

CONSTITUENTS.	X.	XI.	XII.	XIII.	XIV.
Silica (SiO_2)	71.58	54.10	60.80	65.60	63.00
Alumina and Iron (Al_2O_3, Fe_2O_3)	17.93	32.38	26.20	27.12	24.40
Lime (CaO)	1.46	7.03	9.74	6.16	2.85
Magnesia (MgO)	1.67	0.86	3.15	.....	trace

CONSTITUENTS.	XV.	XVI.	XVII.	XVIII.	XIX.
Silica (SiO_2)	61.10	62.30	60.80	63.50	59.10
Alumina and Iron (Al_2O_3, Fe_2O_3)	24.60	29.25	26.50	20.80	24.50
Lime (CaO)	1.99	1.79	1.37	5.66	2.53
Magnesia (MgO)	none	none	trace	.....	.....

I., VII. Blue clay. C. M. Fassett, analyst.
II.-VI., VIII.-X. Buff clay. C. M. Fassett, analyst.
XI. Blue clay. O. P. Moore, analyst.
XII., XIII. Buff clay. O. P. Moore, analyst.
XIV., XV. Blue clay. J. W. Walters, analyst.
XVI.-XIX. Buff clay. J. W. Walters, analyst.

The above analyses are of samples taken from various places over these deposits and from various depths. The deepest shaft was sunk to a depth of about 27 feet. The deposits have been thoroughly sampled and analyzed, and the composition is well shown in the preceding analyses.

Cedar creek rises to the west and north of Cement, flows to the south and east, and empties into the Pend Oreille river at Ione almost a mile south. About one and a fourth miles above the mouth of Cedar creek a dam has been built across it and a ditch and flume about one and three-fourths miles long constructed. In this way the water from Cedar creek was brought around the hillside and delivered to the plant with a vertical head of 106 feet. By means of a 28 inch steel penstock and a Pelton wheel, about 250 horsepower was developed.

Across the Pend Oreille river from Cement are also limestone deposits which have been located, but so far practically no development work has been done. In appearance these limestones are very similar to those on the west side of the river.

Deposits of clay occur at a number of places along the Pend Oreille river between Newport and Cement and these should be carefully sampled and analyses made of them to see if they could be mixed with limestone and used in the manufacture of Portland cement.

From the lower end of Box canyon to Metaline the wagon road follows the west side of the river and shales and clays have been exposed at a number of places in building it. Two samples of these were taken and have been analyzed. The sample of shale was from a large exposure about three miles above Metaline. It is very dark colored, almost black, before pulverizing and dark gray after grinding. It occurs exposed along the road for at least one-half mile and is undoubtedly in very large quantities. It is finely laminated and very fine grained.

Two miles above Metaline, along the wagon road, is an exposure of a buff clay. This is exposed along the road for about 300 feet and in places the deposit shows a thickness of 12 to 15 feet.

The following analyses show the composition of the shale and clay from near Metaline:

ANALYSES OF SHALE AND CLAY FROM NEAR METALINE, PEND OREILLE COUNTY.

A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	14.76	54.88
Alumina (Al_2O_3)	2.80	20.08
Iron (Fe_2O_3)		7.57
Lime (CaO)	42.63	3.98
Magnesia (MgO)	2.26	3.08
Loss on ignition	35.84	8.61
Total	98.29	98.20

I. Shale.
II. Clay.

The analysis shows this shale to be low in silica, iron, and alumina. The amount of iron and alumina are especially small. It is very calcareous and effervesces freely in dilute hydrochloric acid. The color is probably due very largely at least to organic material.

The clay is also a little low in silica and especially when compared with the amount of iron and alumina. When treated with dilute hydrochloric acid it effervesces slightly, showing the presence of some carbonate. The deposit from which this sample was taken is not uniform throughout, some layers being much more sandy than others.

From the above analyses neither the clay or the shale alone appear to be very desirable materials to mix with limestone in the manufacture of Portland cement. Combinations of the clay and shale in certain proportions might be made so as to give the proper amounts of the silica and alumina. These deposits are worthy of careful consideration and should be thoroughly sampled and analyzed. The quantity is certainly very great.

METALINE FALLS.

Metaline Falls is on the Pend Oreille river, about 12 miles below Cement, or 72 miles below Newport and on the opposite side of the river from the old town of Metaline. It is also the

present northern terminus of the Idaho and Washington Northern Railway, which follows the Pend Oreille river from Newport to this point. The railway crosses to the east side of the river just at the lower end of Box canyon and follows down this side until it is a little below the old town of Metaline where at present it stops.

Inland Portland Cement Co.—The property and plant of the Inland Portland Cement Company is situated at Metaline Falls, where a new town is rapidly being built. Large deposits of limestone, shale and clay occur here.

Field Examination.—The limestones, shales, and clays that were examined all lie on the east side of the Pend Oreille river, and are owned by the Inland Portland Cement Company. The limestone is about 750 feet above the factory site on the north hill side. The deposit has been prospected thoroughly and is known to extend at least 1,500 feet east and west, 600 feet north and south, and to have a thickness of at least 300 feet. The limestone varies somewhat in color, some of it being light colored while much of it is very dark. It shows practically no stratification, and is badly broken and seamed, indicating much disturbance.

The shales which occur here are well exposed on Sullivan creek and are just below the limestone. They vary more or less in color, in some cases being almost black and like slate in structure and appearances, while in others they are light gray in color, and have much more of the structure characteristic of shales. They occur in very large quantities in this locality.

Clays are also found in this locality, and so far as could be determined, are very extensive. They show marked stratification, the individual layers being comparitively thin.

All of these materials are easy of access and can be readily brought to the factory at small expense. Sullivan creek furnishes a magnificent power for driving all of the machinery and an electrical plant has been installed. It is claimed that from 15,000 to 20,000 horse power can be developed.

Limestone.

Laboratory Examination.—The limestone is all very compact and fine grained, the light colored stone being a little coarser grained than the dark. The light colored is completely dissolved in dilute hydrochloric acid, but does not effervesce as rapidly as many limestones. The dark colored one dissolves rather slowly, leaving a small dark colored residue which is probably largely organic matter.

The following analyses show the chemical composition of these two samples:

ANALYSES OF LIMESTONE FROM METALINE FALLS, PEND OREILLE COUNTY.

A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	1.32	2.32
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.72	1.52
Lime (CaO)	54.86	51.74
Magnesia (MgO)	0.70	1.89
Loss on ignition	42.84	42.40
Total	100.44	99.89
Calcium carbonate ($CaCO_3$)	97.96	92.39

I. Light colored limestone.
II. Dark colored limestone.

The above analyses show each of these samples to be very high grade limestones. Number one is very low in everything but the lime and especially high in this. Number two, while not quite so high in lime, is still high grade limestone. It is especially low in alumina, iron, and magnesia.

A large number of analyses of this limestone have been made by people interested in the Inland Portland Cement Company and it is said it will average 96.20 per cent calcium carbonate ($CaCO_3$) with only 2.27 per cent of magnesium carbonate.

Shale.

The shales which occur on Sullivan creek all appear very fine grained, the lighter colored ones have a slightly slick or greasy feel, and are not very finely laminated. The dark colored ones, in places at least, show much iron sulphide in very minute

Clay Quarry of the Superior Portland Cement Company at Concrete.

particles disseminated through them. These shales all carry more or less calcium in the form of carbonate and hence effervesce on the addition of dilute hydrochloric acid. They are all lighter colored when pulverized than they are when in large masses.

The following analyses show the chemical composition of two samples of this shale. One was dark gray in color while the other was black.

ANALYSES OF SHALE FROM SULLIVAN CREEK, METALINE FALLS, PEND OREILLE COUNTY.

A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	44.16	48.22
Alumina (Al_2O_3)	19.63	17.46
Iron (Fe_2O_3)	6.09	4.38
Lime (CaO)	13.06	12.10
Magnesia (MgO)	2.15	2.24
Loss on ignition	14.36	11.29
Total	99.45	95.69

I. Light colored shale.
II. Almost black shale.

The two samples as shown by the above analyses do not differ very much in composition. Each one of them is a little low in silica especially as compared with the amount of iron and alumina that they contain. The amount of magnesia is not large and this is a point in their favor.

The following chemical analyses of these shales were furnished by the Inland Portland Cement Company:

ANALYSES OF SHALE FROM SULLIVAN CREEK, METALINE FALLS, PEND OREILLE COUNTY.

Silica (SiO_2)	41.61	23.54	10.54	48.26
Alumina and Iron (Al_2O_3, Fe_2O_3)	22.84	15.20	6.42	21.84
Lime (CaO)	15.07	30.22	43.01	12.10
Magnesia (MgO)	2.83	2.38	2.99	2.24

The above analyses show a considerable variation in the shales found here. The amount of magnesia in all of them appears to be low and quite constant as shown by all the analyses. The ratio between the silica and alumina and iron also appears

to be quite constant. In the analyses made by Mr. Hammer as already pointed out, the silica is low for the amount of alumina and these analyses show the same thing.

Shales also occur at the mouth of Sand creek where it empties into the Pend Oreille river, about four miles above Metaline Falls. These shales are being used by the Inland Portland Cement Company, and the following analyses were furnished by this company:

ANALYSES OF SHALE FROM SAND CREEK, METALINE FALLS, PEND OREILLE COUNTY.

CONSTITUENTS.	I.	II.	III.	IV.	V.
Silica (SiO_2)	72.04	70.84	69.40	66.04	65.64
Alumina and Iron (Al_2O_3, Fe_2O_3)	13.72	14.40	14.20	14.12	11.20
Lime ($CaCO_3$)	4.07	5.00	6.26	6.57	9.70
Magnesia ($MgCO_3$)	4.13	4.13	4.34	6.95	9.44
	VI.	VII.	VIII.	IX.	X.
Silica (SiO_2)	65.96	67.08	65.72	66.48	70.68
Alumina and Iron (Al_2O_3, Fe_2O_3)	12.64	10.84	8.84	12.08	12.80
Lime ($CaCO_3$)	9.92	9.55	12.99	11.42	6.10
Magnesia ($MgCO_3$)	8.75	8.60	10.15	8.40	7.12
	XI.	XII.	XIII.	XIV.	XV.
Silica (SiO_2)	71.12	71.40	68.40	74.40	74.12
Alumina and Iron (Al_2O_3, Fe_2O_3)	13.36	14.04	12.04	13.00	12.16
Lime ($CaCO_3$)	5.32	5.48	9.55	2.81	5.00
Magnesia ($MgCO_3$)	5.30	6.81	6.39	4.78	6.06

II.-III. Individual samples from different points in the quarry. Other analyses show composition of this material as used in the mill.

The analyses given above are all of samples of what has been designated as diamond shale from the Black Diamond claim owned by the Inland Portland Cement Company, and cover a period of two years working, from May 24, 1911, to May 13, 1913.

One of the striking things shown by the above analyses is the uniformity in composition of these shales. They are especially high in silica, however, for the amount of alumina and iron which they contain. They also contain a rather high percentage of magnesia and if a large amount of this shale were used it might increase this substance above the maximum allowed in

a Portland cement. This should be a good material to mix with the shale or clay from Sullivan creek and from this mixture a good Portland cement should be made.

Clay.

The clays which occur here vary somewhat in color and composition. They are all fine grained and free from gritty material. The deposits, in places at least, have some layers that appear quite sandy. These clays absorb water rapidly and slack, breaking into a mass of very fine particles. In color when dry they are brownish or bluish and when wet some of them are dark blue.

The following analysis shows the composition of one sample of the clay from here:

ANALYSES OF CLAY FROM METALINE FALLS, PEND OREILLE COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	63.40
Alumina (Al_2O_3)	16.10
Iron (Fe_2O_3)	4.10
Lime (CaO)	5.34
Magnesia (MgO)	2.75
Loss on ignition	5.00
Total	96.69

The above analysis shows the silica in this clay to be just a trifle high for the amount of alumina that it contains. The percentage of iron, while not large, would have a tendency to make this clay fuse at a fairly low temperature. While the amount of the alkalies present was not determined, there is undoubtedly more or less of them in the clay and these again would help to lower the temperature at which this clay would fuse.

Two analyses of these clays were furnished by the Inland Portland Cement Company and are given below:

ANALYSES OF CLAY FROM METALINE FALLS, PEND OREILLE COUNTY.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	63.20	57.02
Alumina and Iron (Al_2O_3, Fe_2O_3)	20.20	20.62
Lime (CaO)	5.34	7.01
Magnesia (MgO)	2.75	3.67

I. Grayish colored clay.
II. Blue clay.

The above analyses show the blue clay contains a little less silica than the other and would indicate that it is a little better clay than the other for use in the manufacture of Portland cement.

It would seem that the best results might be obtained by using a mixture of the clay, shale, and limestone found here. The limestone is especially pure. The shale a little low in silica for the alumina, while some of the clay, at least, is a little high in silica and if these are mixed in certain proportions the proper ratio should be obtained.

Description of the Plant.—The construction work on the plant of the Inland Portland Cement Company was commenced on the first of June, 1910, and the mill completed on the first of April, 1911. Through a delay in completing the water power development, the plant was not in operation until the first of August, although the mill was entirely completed.

Construction of a plant at Metaline Falls involved the development of a water power of the high head class—approxiately a five hundred foot head, and the completion of the power plant represented a number of engineering questions.

In obtaining available water is was required to dam Sullivan lake, on the Kaniksu national forest, and to divert the water of Sullivan creek by a diversion flume into the lake proper. Through the dam and diversion of Sullivan creek, Sullivan lake, covering an area four miles long by a mile wide, was raised approximately twenty-five feet, offering an enormous reserve of water. From the dam at Sullivan lake the water was allowed to pass through the regular channels of Sullivan creek to the reservoir at dam number two. At this point a reservoir was made by building dikes and daming a large flat of forty to sixty acres and from this reservoir the water enters the flume proper. Regulating gates at the flume control the volume of water admitted and maintain an equal depth at the forebay. The flume is of wooden construction, eight feet in width, by six feet deep, and 13,000 feet, or two and one-half miles, in length, from the reservoir to the entry of the main ditch or canal.

The flume is constructed on bed rock, along the side of the mountain, and in places almost a thousand feet above the level of the water of Sullivan creek. From the flume the water passes into the main ditch leading to the forebay, and at that point the volume is controlled by a second series of head gates. Through these head gates the water enters the tunnel leading to the power house, and, in a distance of fourteen hundred feet, has a vertical head of four hundred and eighty feet. The resultant pressure is two hundred pounds per square inch, as delivered to Pelton impulse water wheels.

The power installation consist of two Westinghouse generators, 1785 K. V. A., direct connected to Pelton water wheels, combined with the required exciters and switchboards. The current is developed at 2300 volts, and transformed at the mill to a 550 volt base for operating purposes.

The Quarries and Works.

The raw materials used in the manufacture of "Inland" Portland cement are limestone and shale, and inexhaustible quantities are available on the properties at Metaline Falls. The limestone quarries are 2,700 feet from the plant proper and consist of a high quality of limestone in the open quarry formation. The usual methods of quarrying are used, consisting of air drills, shovels, and cars for delivery to the crushers.

The crushing plant consists of one No. 9, style "K" Gates breaker and two No. 5, style "K" Gates breakers. From the No. 5 crushers the stone is conveyed to the storage bins, and from the storage delivered to the mill by Leschen automatic trams. The trams operate on the gravity system, and generate sixteen horse power in excess of the amount required to return the empty buckets. The required shale is quarried at a point directly back of the power station, and is conveyed to the raw storage department by a short tram of the Leschen power-operated type.

The raw materials, limestone and shale, are delivered into the raw storage department by the trams, and drawn from the storage by a system of tunnels and conveyors, eliminating labor

in handling. They are fed automatically into two Vulcan rotary dryers, each seven feet in diameter and sixty feet long, the two materials passing through the rotary dryers entirely separate, and, after a thorough drying, are stored in bins above the automatic weighing machines. From the storage bins above the automatic weighing machine, the raw materials, limestone and shale, are weighed separately and dumped on a conveying belt in the proper proportions.

From the scales the raw material is conveyed to type "B" Jeffrey hammer mills, for the preliminary grinding, and from that point to the stock bins above the 40 inch giant Griffin mills. These mills complete the raw grinding by rendering the raw material to an impalpable powder of a fineness so that 95 to 98 per cent. of it will pass a 100 mesh sieve. The 40 inch Griffin mills weight 26,000 pounds each and are the most modern type of grinding machines in the cement industry. These machines are driven by 75 H. P. vertical motors of the General Electric type, and have a capacity of four tons per hour on raw material of this class. Screw conveyors carry the powdered raw materials to the stock bins of the rotary kilns, and from that point the material is fed automatically into 9′ 6″ x 140′ rotary kilns.

In order to thoroughly flux the two materials an intense heat is required, and this is obtained through the burning of finely powdered coal. The coal is ground in the coal grinding department of 40 inch Griffin mills, and in the powdered state conveyed to the coal stock bins in front of the rotary kilns. From the coal bins the pulverized coal is conveyed to a blast pipe and blown into the kilns by air pressure. The contact of the powdered coal with the intense heat results in an explosion and a resultant temperature of 2,700° to 3,000° Fahrenheit. By this intense heat the raw material is calcined and thoroughly fluxed, leaving the kilns in the form of a red clinker, which on cooling turns to a sparkling green-black color. The rotary kilns are operated by 50 H. P. General Electric variable speed motors, and the coal feed has a mechanical variable speed control.

The rated production of a 9′ 6″ x 140′rotary kiln is 1,000 barrels of clinker in twenty-four hours, and the producing capacity of the two kilns at Metaline Falls works approximates eighteen hundred barrels in the twenty-four hour period.

After cooling, the clinker is conveyed to the automatic scales for weighing and the addition of the required amount of gypsum. The preliminary reduction of the clinker is made on Sturtevant rotary crushers, and from that point it is conveyed to the stock bins in the clinker grinding department. The finished grinding is done on 40 inch Griffin mills, and a fineness obtained so that 96 to 97 per cent. will pass the 100 mesh sieves and 85 per cent. the 200 mesh sieves. These mills are also operated by 75 H. P. vertical motors. The plant is practically limited to this one class of grinding machines.

From the clinker grinding department the finished cement is conveyed to stock houses for storage until delivery is required. The storage capacity, consisting of two stock houses, will contain 250,000 barrels of finished cement.

In connection with the power development the city of Metaline Falls is furnished with light and power, and the surrounding mines have an available supply of electrical power to the extent of 10,000 H. P. Incidental to the cement plant proper are the machine shop, consisting of concrete building and modern equipment, and the stores department, containing all repairs and renewal parts for the plant and power station. The plant and plant development represent an investment of $1,400,000 and a monthly pay roll and purchasing expenditure of $45,000.

CHAPTER VIII.

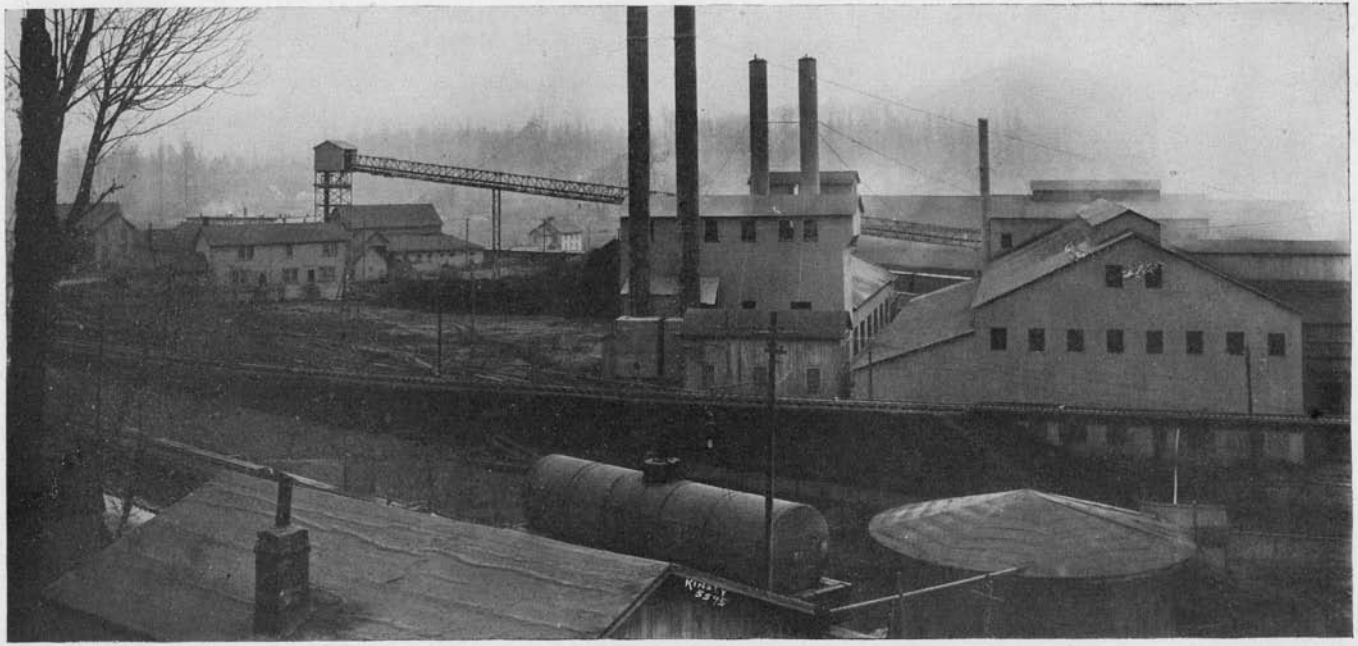
CEMENT MATERIALS OF WESTERN WASHINGTON.

The geology of that part of Washington west of the Cascade mountains is very different from that part to the east of them. In western Washington there are large areas that are made up of various kinds of sedimentary rocks, such as sandstones, shales and rocks of this general character. Clays are widely distributed and are of good quality. One of the essentials, however, for Portland cement, the limestone, is confined to a few localities and occurs in these only in comparatively small amounts. The only limestone deposits so far known which may possibly be of importance are in King, Snohomish, Skagit, Whatcom and San Juan counties. In eastern Washington the limestone deposits with one exception are in the northern part of the state. In western Washington all of the deposits of any importance are north of 48° north latitude and on account of this the manufacture of Portland cement in western Washington will in all probability always be confined to the northern part of the state.

The limestone deposits of western Washington occur in comparatively small isolated bodies and are not continuous over large areas. In many cases, however, they contain large quantities of limestone. As in eastern Washington, they are apparently simply the remains of a much larger body which perhaps covered a large part of northern Washington. Fossils are found at but few places in these deposits and these are poorly preserved and so far have not been identified, so the age of the limestone is not known.

SAN JUAN COUNTY.

San Juan county is in the northwestern part of the state and consists entirely of a group of islands situated between the Gulf of Georgia on the north, Strait of Juan de Fuca on the south, the shores of Whatcom and Skagit counties on the east, and Vancouver Island on the west.



General View of the Plant of the Washington Portland Cement Company at Concrete.

TOPOGRAPHY.

The county in the main is not far above sea level and consists of comparatively level tracts, areas of low hills, and in some few cases hills from 500 to 1,000 feet above sea level. Mt. Constitution, the highest mountain in the county, reaches a height of 2,428 feet above sea level. Some of the islands are entirely free from hills and are but a short distance above the surface of the water. Low fertile valleys occur in many places on the islands throughout the county.

GEOLOGY.

Sedimentary and igneous rocks are common throughout the different parts of the county. Some of the islands in the northern part of the county are composed entirely of sedimentary rocks. These are massive sandstones and conglomerates and are mostly very dark in color. In places these sandstones contain fossils in abundance which have been identified as belonging to the Cretaceous age.

A large part of San Juan county consists of metamorphic rocks. These rocks cover large areas and all of the higher points especially consist of them.

In places in the county large bodies of clay are found which are of good quality for certain purposes. Limestones are found in places on some of the islands and the manufacture of lime has become a very important industry.

SAN JUAN ISLAND.

This is the largest island in the county and contains the largest body of limestone and more lime is burned here than at any other place in the state.

The following in regard to the Roche Harbor lime deposits in San Juan county is from Professor Henry Landes' report on the Cement Resources of Washington.*

"The limestone has been rendered entirely crystalline by metamorphism, and any fossils which it may have contained

*Bulletin, U. S. Geological Survey, No. 285, pp. 377-378.

have been destroyed. The limestone is one of a series of metamorphic rocks which have been greatly contorted and faulted and its geological age has not been accurately determined. It is without doubt older than the Cretaceous rocks which form the bulk of the small neighboring island a few miles to the north.

"At Roche Harbor the limestone occurs as two large ledges with a strike a little east of north. In outcrop they extend from north to south about one-half mile, and from east to west about 1,000 feet. The height of the limestone above the tide water averages 200 feet; its depth below the ocean has not been determined. The fact that the limestone is much broken and but little stripping is required, makes it possible to quarry the stone and deliver it to the crusher at a minimum expense. The quarry at this place has been in operation since 1882 and the manufacture of lime amounts to about 300,000 barrels per year. The limestone varies but little in composition and is very uniform in character.

"Adjacent to the limestones there are large deposits of glacial sediments which contain extensive beds of clays interstratified with sands. Some of the clay beds are known to be at least 40 feet in thickness and they have been so thoroughly washed as to be unusually free from gritty ingredients. In case the clays do not afford enough silica for use in cement manufacture it may be easily obtained from the quartzites and slates that are near at hand as members of the metamorphic series of which the limestone is a part.

"A cement plant built at Roche Harbor could be so arranged that the limestone at least might be transported to the mills by a gravity system. The final product could also be transported in the same manner to warehouses on the wharf. The harbor here is well protected and the water is sufficiently deep for ocean-going vessels to enter and depart at any tide."

The following analyses are from the same authority and show the chemical composition of the limestone, clay, slate, and quartzite from San Juan island:*

*Bulletin, U. S. Geological Survey, No. 285, p. 378.

ANALYSES OF LIMESTONE, CLAY, SLATE, AND QUARTZITE FROM ROCHE HARBOR, SAN JUAN COUNTY.

CONSTITUENTS	LIMESTONE			CLAY		SLATE	QUARTZITE	
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Silica (SiO_2)	0.44	0.27	0.20	55.81	56.35	78.00	72.32	84.84
Alumina and Iron (Al_2O_3, Fe_2O_3)	1.13	0.21	0.30	26.28	24.62	6.98	10.11	6.78
Calcium carbonate ($Ca\,CO_3$)	98.21	99.06	98.57	4.34	3.66	6.45	7.25	3.63
Magnesium carbonate ($Mg\,CO_3$)	.....	0.46	1.02	3.39	2.58	1.56	2.24	0.80
Sulphur (S)	.....	.....	.....	trace	0.31	trace	0.07	trace
Alkalies (K_2O, Na_2O)	.....	.....	.....	3.98	3.94	1.56	1.11	trace
Moisture (H_2O)	.....	.....	.....	6.11	7.52	0.30	0.45	.....
Carbonic acid	.....	.....	.....	.....	.....	5.15	5.01	3.41
Totals	99.78	100.00	100.09	99.91	98.98	100.00	99.06	99.46

I. Analyzed in 1888 by Moss Bay Hematite and Iron Company (Limited), Workington, England.
II. Analyzed in 1893 by Puget Sound Reduction Company, Everett, Wash.
III. Analyzed in 1902 by C. F. McKenna, New York City.
V.-VIII. Analyzed by F. C. Newton, Seattle, Washington.

The analyses of the limestone all show a very high percentage of lime and very little impurities, the amount of magnesia being very small. The analyses of the clay show it to be about the average in composition of the common clays. It is not high in silica, but the ratio between the silica and the sum of the iron and alumina is very fair. The amount of magnesia in the clay is also low and from the above analyses it appears to be well suited as a material to mix with the Roche Harbor limestone in the manufacture of Portland cement.

While limestones occur at other places on the island the Roche Harbor deposits are the only ones of importance, the others being small.

ORCAS ISLAND.

This island is next to the largest island in size of those composing San Juan county. At a number of places on this island are bodies of limestone of greater or lesser extent. Large deposits of clay are also found in places. The general geology of the island appears to be very similar to that of San Juan island.

Limestone.

The limestone deposits that occur on Orcas island are isolated bodies and in all cases are not very extensive. At least five different exposures of this character are known to occur at different places on the island. Three of these are being worked, the stone from two of them being used in the manufacture of lime, while from the third it is loaded onto scows and taken to the Tacoma smelter where it is used as a flux. These deposits are all very similar in occurrence. They all constitute a part of the metamorphic series which is widely distributed over the island. No fossils have been found in these limestones and their age is not known. The deposits are massive and show but little signs of stratification. Most of the deposits occur along the waters edge only a short distance above sea level. This would make it possible to use a gravity method in handling the material from the quarry to the boat.

The Cowles lime deposits are in section 31, township 37 north, range 3 west and section 36, township 37 north, range 2 west and are about four miles almost north of West Sound. The deposit shows a height of about 50 feet and breadth of 50 feet. The limestones here are being quarried and used for the manufacture of quick lime.

In section 25, township 37 north, range 2 west is a deposit of limestone which is being quarried and shipped to Tacoma for use in the smelter that is located there. This deposit, which is situated on the east side of East Sound, about two and one-half miles from the town of East Sound, rises from the water's edge to a height of about 75 feet and outcrops along the bluff for more than 200 feet. This deposit is one of the largest ones on the island.

Across East Sound, almost due west from the above described deposit, is another body of limestone. This is in section 2, township 36 north, range 2 west. No work has been done on this deposit, but in general appearance it is very similar to the others.

The Mount Constitution Lime Company has lime deposits

situated in section 19, township 37 north, range 1 west and some development work has been done. This deposit, where exposed at least, lies back about 3,000 feet from the water's edge, at an elevation of 350 feet above high tide. Limestone is exposed for about 500 feet along the surface and in places a thickness of from 25 to 40 feet is shown.

The Orcas Island Lime Company is working a deposit of limestone that is situated in section 31, township 37 north, range 2 west. This deposit as far as could be told is only a very small one and in general appearance is similar to the others.

Laboratory Examination.—The limestones which occur on Orcas island are more or less variable in color and range from very dark to almost white. They are entirely crystalline, in some cases being coarse textured, while in others they are quite fine grained. When powdered, the limestones are almost white and dissolve readily in dilute hydrochloric acid with rapid effervescence.

The following chemical analyses show the composition of a number of samples of the limestone from these deposits:

ANALYSES OF LIMESTONE FROM ORCAS ISLAND, SAN JUAN COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.	III.
Silica (SiO_2)	1.14	1.64	4.28
Alumina and Iron (Al_2O_3, Fe_2O_3)	trace	0.06	0.96
Lime (CaO)	54.44	54.43	52.36
Magnesia (MgO)	0.31	0.39	0.64
Loss on ignition	43.11	43.30	42.00
Total	99.00	99.82	100.24
Calcium carbonate	97.21	97.21	93.50

I. Limestone used by the Cowles Lime Company.
II. Limestone used by the Tacoma smelter.
III. Limestone from deposits of the Mount Constitution Lime Company.

The above analyses show all the samples to be good, high grade limestone. They are almost entirely free from magnesia, as well as all other impurities.

Most of these deposits, if not all of them, are small and on account of this any one of them by itself would have but little commercial value as material to be used in the manufacture of

Portland cement. It would be possible, however, to transport the limestone from any of these deposits to a plant located most any place on the island and in this way all of the deposits might be used by one factory.

Clay.

Clay occurs in section 21, township 37 north, range 1 west and at one time a brick yard was operated here. This clay covers a large area and has a thickness, in places at least, of twenty feet or more. The best clay occurs a little below the surface.

The clay found on Orcas Island is light gray in color with a slightly yellowish tinge. It absorbs water rapidly and slacks, breaking into a mass of very minute particles. The clay is fine grained, but contains considerable gritty material. It has good plasticity and works easily.

The following chemical analysis shows the composition of this clay:

ANALYSIS OF CLAY FROM ORCAS ISLAND, SAN JUAN COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	59.92
Alumina (Al_2O_3)	21.08
Iron (Fe_2O_3)	4.56
Lime (CaO)	3.88
Magnesia (MgO)	2.90
Potash (K_2O)	1.16
Soda (Na_2O)	0.97
Loss on ignition	4.74
Total	99.21

The above analysis would indicate that this is a very fair clay for use in the manufacture of Portland cement. The percentage of alumina is a trifle high, the amount of iron is a little low and the amount of magnesia is not large. The total of the fluxing substances is great enough so that this clay should fuse at a comparatively low temperature.

Professor Henry Landes, in his article entitled "Cement Resources of Washington," gives the following analyses of limestone, shale, and clay from Orcas Island:

ANALYSES OF LIMESTONE, SHALE, AND CLAY FROM ORCAS ISLAND, SAN JUAN COUNTY.*

CONSTITUENTS.	Limestone.		Shale.		Clay.	
	I.	II.	III.	IV.	V.	VI.
Silica (SiO_2)	1.61	1.14	62.80	39.80	57.30	53.20
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.04	.....	19.20	21.62	21.40	23.90
Calcium ($CaCO_3$)	97.45	97.23	10.20	29.10	5.10	6.30
Magnesium ($MgCO_3$) ..	.....	0.31	0.90	2.91	3.10	4.10
Sulphur	trace	trace	.....	0.41	0.50	0.80
Alkalies (K_2O, Na_2O) etc.	0.51	1.21	undt.	2.15	2.10	2.90

*Bulletin U. S. Geological Survey, No. 285, p. 378.

LOPEZ ISLAND.

Clay.

This is the third largest island in the county. It is south of Orcas Island and in the southern part of the county. Large deposits of clay occur on the island, but no shales or limestones, so far as the writer is aware, have been found.

Clay occurs on the north end of the island, about three and one-half miles from the town of Lopez. The deposit appears to be very uniform throughout, with scarcely any sandy layers through it, and practically no stratification. There is an exposure along the water of 200 feet with a thickness of from 25 to 30 feet. A well that is one-half mile inland exposes sixteen feet of this same clay and there is undoubtedly a large body of it at this place.

Laboratory Examination.—In general appearance the clay is very similar to that on Orcas Island. The color is light gray with a slightly yellowish tinge. It absorbs water and slacks rapidly, breaking into a mass of very fine particles. When dry it is fairly hard and brittle. It is fine grained and contains some very small particles of gritty material.

The following analysis shows the chemical composition of this clay:

ANALYSIS OF CLAY FROM LOPEZ ISLAND, SAN JUAN COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	59.40
Alumina (Al_2O_3)	19.58
Iron (Fe_2O_3)	6.44
Lime (CaO)	4.26
Magnesia (MgO)	4.13
Potash (K_2O)	0.75
Soda (Na_2O)	0.41
Loss on ignition.....	4.38
Total	99.35

The analysis of this clay shows it to have practically the same composition as the one from Orcas Island. There is a little less alumina, more iron, and more magnesia. The decrease in the amount of alumina makes this clay better suited for cement but the increase in the magnesia has just the opposite effect. The amount of magnesia, however, even in this sample is not excessive and on the whole this would be a good clay to use in the manufacture of Portland cement.

WHATCOM COUNTY.

This county is in the northwestern part of the state. It extends from the Gulf of Georgia on the west to the summit of the Cascade mountains on the east. In altitude it ranges from sea level to 10,827 feet above. In the western part of the county glacial deposits are very common. Beneath the glacial deposits the rocks are mainly sedimentary and consist of sandstones, shales, and slates and belong, at least in part, to the Puget formation. The eastern part of the county is rough and mountainous and the rocks are largely igneous and consist of granites, gneisses, schists, and slates. In the northern part of the county, a short distance west of its center, are also some limestone deposits of a very local character.

KENDALL.

Limestone.

Kendall is on the line of the Bellingham Bay and British Columbia railway, about twelve miles southwest from Sumas. Limestone, shale, and slate are found around here in a number of places and some development work has been done.

Field Examination. — The limestone occurs in isolated masses, covering comparatively small areas. The deposits show no signs of stratification and fossils are found in them in but one or two places. The limestone occurs on either side of the railroad a few miles north of Kendall. A small creek flows south from Columbia valley and the hills along either side of this rise to considerable height. On the east side of this creek the limestones lie high above the valley, but on the west side they begin low down on the side hill about on a level with the valley.

Tube Mills in the Plant of the Washington Portland Cement Company at Concrete.

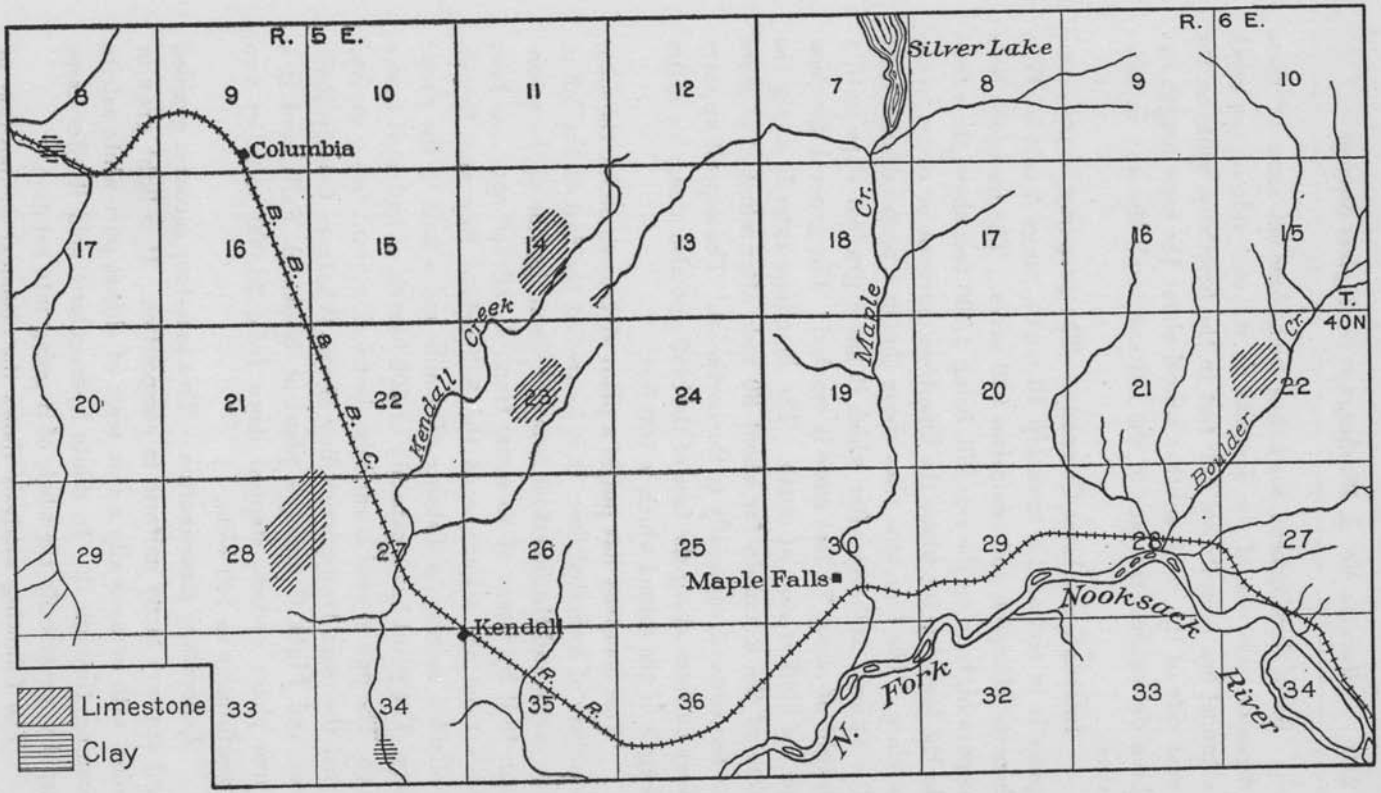


FIG. 9. Limestone and Clay deposits near Kendall, Whatcom County.

Some development work has been done on some of these deposits. On one of the deposits on the east side of the creek a tunnel has been driven 100 feet in the limestone, while on the west side of the creek another tunnel about the same length has been driven into the face of the hill and is all the way in limestone.

International Lime Company.—The property of this company is in section 14, township 40 north, range 5 east of Willamette Meridian and comprises 320 acres. The limestone here occurs high up on the side hill, being 1,700 feet above the valley to the lowest point where the limestone outcrops or comes to the surface. The limestone rises above this in a perpendicular bluff for at least 200 feet after which it has a gradual slope until a height of about 75 feet more is reached. The general direction of the bluff is east of north. The limestone extends along the face of the mountain for about 80 rods after which it is more or less covered, especially to the northeast. The deposit appears very uniform along the face of the bluff and also along the entire length of the tunnel which is 100 feet.

This company has put in a plant at Limestone for the manufacture of hydrated lime. It is located at the foot of the hill in the valley and the limestone brought down the side of the mountain to it by means of an aerial tram. A railroad spur has been built from the main line of the Bellingham Bay and British Columbia railway, a distance of a mile and a half to the property. The plant has a capacity of 500 barrels of hydrated lime a day. The power used is entirely electrical, current being derived from the main transmission line of the Whatcom County Railway and Light Company's plant at Nooksack Falls, and is a three phase system, stepped down from 38,000 volts by two transformers to 440 volts.

Laboratory Examination.—This limestone is coarse grained and appears fairly uniform in composition. It is light gray in color, with occasionally a thin seam of almost pure white calcite running through it. In dilute hydrochloric acid it effervesces rapidly, practically the whole of it going into solution.

The following analysis shows the chemical composition of a sample of this limestone:

ANALYSIS OF LIMESTONE FROM LIMESTONE, WHATCOM COUNTY.

Silica (SiO_2)	1.32
Iron and Alumina (Fe_2O_3, Al_2O_3)	0.50
Calcium carbonate ($CaCO_3$)	97.58
Magnesia ($MgCO_3$)	0.36
Alkalies by difference	0.24
Total	100.00

Northwestern Portland Cement Company.—The property of this company is in the north half of the northeast quarter of the southwest quarter of section 23, township 40 north, range 5 east, Willamette Meridian, and is a little more than a mile southwest from the property of the International Lime Company. The deposits lie high up on the hill side at least 1,000 feet above the valley. The limestone occurs in more or less isolated bodies of rather small extent with masses of what appear to be metamorphic rocks coming up between them. The limestone outcrops at various places along the hill side for a considerable distance. The appearance, however, is that the limestone simply lies on the face of the hill and does not have any very great thickness. Scarcely any work has been done here and it is hard to say positively in regard to the extent of these deposits, but the indications are that they are not large.

Laboratory Examination.—In general appearance the limestone from this property is very similar to that which occurs to the northeast of it. It is dark gray in color and coarsely crystalline in texture. It effervesces rapidly in dilute hydrochloric acid and practically all dissolves. In places it has a small amount of cherty appearing material in it. This, however, is not common and constitutes a very small part of the samples examined.

The following chemical analysis shows the composition of this limestone:

ANALYSIS OF LIMESTONE FROM NEAR KENDALL, WHATCOM COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	1.44
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.92
Lime (CaO)	54.36
Magnesia (MgO)	trace
Loss on ignition	43.17
Total	99.89
Calcium carbonate ($CaCO_3$)	97.07

This is a very high grade limestone and the only question in connection with these deposits is the one of quantity.

Balfour Guthrie Company.—The property owned by this company is on the west side of the valley and about one-half a mile west of the railroad. The deposits are in the southwestern part of section 22, township 40 north, range 5 east. The limestone at this place begins on a level with the valley and extends up the face of the mountain for at least 200 feet. The horizontal exposure is about 100 feet. To the northeast, however, a distance of about one-fourth of a mile, the limestone occurs on the surface. Whether these two outcrops are continuous or not is not known as the side hill is covered with soil and dense vegetation and no outcrops were found. The limestone here shows no signs of stratification and the color ranges from light, almost white in places, to a dark gray. A tunnel has been driven into the side hill on the limestone for about 100 feet. The limestone appears somewhat different in the first part of this tunnel from what it does in the last part. The first 50 feet of the tunnel is through a whiter colored and what appears to be a purer limestone than that through which the last 50 feet passes.

Laboratory Examination.—The hand samples from this deposit show considerable variation in this limestone. Some of them are almost pure white and apparently quite free from foreign substances, while others are dark colored and contain a considerable amount of cherty appearing material. In texture they are mostly rather coarsely crystalline. In dilute hydrochloric acid the limestone dissolves with rapid effervescence, the lighter colored one going completely into solution, while in the case of the darker colored ones a very slight amount of sediment remains.

The following analyses show the chemical composition of this limestone:

ANALYSES OF LIMESTONE FROM NEAR KENDALL, WHATCOM COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	3.04	8.96
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.76	2.44
Lime (CaO)	52.48	48.46
Magnesia (MgO)	0.30	1.01
Loss on ignition	42.14	39.16
Total	98.72	100.07
Calcium carbonate ($CaCO_3$)	93.71	86.53

I. Taken as an average surface sample.
II. Taken along the last 50 feet of tunnel.

The above analyses show a considerable difference in the composition in these two samples. Each of these analyses represents the results on composite samples, each sample representing a considerable part of the deposit. Number one has a fair percentage of lime with practically no magnesia and but very little iron and alumina. Number two has less lime and more silica, iron and alumina, and magnesia. This is due to the fact, with the exception of the magnesia, that this sample contained considerable cherty material. This limestone is below the average of the limestones being used by the Portland cement plants in the United States, but, owing to its very low percentage of magnesia, it might be of value. The deposit does not show as good limestone as those on the east side of the valley.

Clays.

Clays are found in a number of places around Kendall. About five miles northwest from Kendall, along the line of the Bellingham Bay and British Columbia railway, is a body of stratified clay which has been exposed along the railroad where it cuts through it. This exposure shows a thickness of 20 feet and extends along the railroad a distance of 300 feet. This same clay is known to extend back toward the mountain for at least a half a mile and borings have been made which show it to be much thicker than where it is exposed along the railroad. In some cases a thickness of 50 feet is reported. The deposits lie practically horizontal and appear to be very uniform throughout with scarcely any sandy layers. These deposits are on Mr.

Jacobs' farm, and are in section 9, township 40 north, range 5 east.

Laboratory Examination.—This clay is very fine grained and free from gritty materials of any kind. In color it varies somewhat and ranges from light gray with a bluish tinge, to a light yellow. When pulverized it is light gray in color. It is very hard when dry, absorbs water rapidly and slacks breaking into a mass of very thin small flakes. When treated with dilute hydrochloric acid it effervesces slightly.

The following chemical analysis shows the composition of this clay:

ANALYSIS OF CLAY FROM NEAR KENDALL, WHATCOM COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	59.92
Alumina (Al_2O_3)	17.85
Iron (Fe_2O_3)	7.31
Lime (CaO)	6.08
Magnesia (MgO)	3.15
Loss on ignition	5.42
Total	99.73

The above analysis shows this clay to carry some lime and some magnesia. The amount of magnesia, however, is not especially high. It has a good percentage of silica and the ratio between the alumina and silica is good.

Clay occurs also in section 34, township 40 north, range 5 east, on the farm of Mr. J. J. Eason. Along the creek here the ground is of a marshy nature and it is thought that clay is quite widely distributed through this marsh. Nothing definite, however, is known in regard to the extent of this clay.

Laboratory Examination.—This clay when dry is dark gray in color with a bluish cast, and when wet is dark blue. It is very fine grained and free from gritty particles. It absorbs water and slakes but slowly.

The following analysis shows the chemical composition of this clay:

ANALYSIS OF CLAY FROM NEAR KENDALL, WHATCOM COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	54.16
Alumina (Al_2O_3)	14.97
Iron (Fe_2O_3)	7.91
Lime (CaO)	2.62
Magnesia (MgO)	4.15
Loss on ignition	13.46

The sample from which the above analysis was made contained a considerable amount of organic matter which accounts for the large amount of loss on ignition. The analysis shows a large amount of magnesia and a rather small amount of alumina.

Shales occur in the Kendall district but none of the deposits were examined.

The following analyses of limestone, clay, and slate are given by Professor Henry Landes, in his Cement Resources of Washington:*

CONSTITUENTS.	Limestone		Clay.		Slate.	
	I.	II.	III.	IV.	V.	VI.
Silica (SiO_2)	1.52	1.37	61.27	57.06	66.01	72.69
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.35	0.42	25.30	26.80	17.65	22.19
Calcium carbonate ($CaCO_3$)	97.48	98.72	2.96	10.62	8.01	2.16
Magnesium carbonate ($MgCO_3$)	1.26	0.26	4.68	1.13	3.15	2.47
Alkalies (K_2O, Na_2O)...	.....	.....	.....	2.56	.....	.....

I. and III. analyzed by D. W. Riedle, Montavilla, Oregon.
II., IV., V. and VI. analyzed by A. H. Cederberg.

The above analyses show the limestones to be especially good, as they contain a high percentage of lime and scarcely any magnesia. The clays appear to be very fair. The slates, however, are not especially promising.

MAPLE FALLS.

Maple Falls is on the line of the Bellingham Bay and British Columbia railway, fifteen miles southeast from Sumas and three miles from Kendall.

Limestone is found about four miles northeast of the town of Maple Falls. It occurs on Boulder creek and is in the east half of the northwest quarter of section 22, township 40 north, range 6 east. The deposit at his place occurs in a bluff that rises almost perpendicular above the river. The limestone occurs only on the west side of Boulder creek, the formation on the east side apparently being of igneous origin.

*Bulletin, U. S. Geological Survey, No. 285, p. 379.

The limestone outcrops at about the level of the creek and rises about 60 feet above it. The deposit appears to be very uniform throughout. It occurs massive without any sign of stratification. This deposit was located as a marble property and a little development work has been done. So far as could be told the deposit covers but a very small area. It is exposed along the creek but a short distance and does not extend back from it very far.

Laboratory Examination.—This limestone is coarsely crystalline and rather brittle. In color it varies slightly, some pieces being very light, while others are darker. None of it, however, is very dark. When pulverized it is almost white. It effervesces rapidly in dilute hydrochliric acid, practically the whole of it going into solution.

The following analysis shows the chemical composition of this stone:

ANALYSIS OF LIMESTONE FROM NEAR MAPLE FALLS, WHATCOM COUNTY.

A. A. HAMMER, Analyst.

Silica (SiO_2)	0.48
Alumina and Iron (Al_2O_3, Fe_2O_3)	1.00
Lime (CaO)	52.88
Magnesia (MgO)	2.05
Loss on ignition	43.14
Total	99.45
Calcium carbonate ($CaCO_3$)	94.42

The above analysis shows this to be a very good limestone, the amount of each of the impurities being very small.

BELLINGHAM.

A cement plant has been built at Bellingham and is now in operation. The following description was furnished by the company:

The Olympic Portland Cement Company, Limited.—The plant of this company is located at Bellingham, Whatcom, county, Washington, was the first one to be built on the Pacific Coast primarily as a wet process installation. The designs and greater part of the machinery were supplied by the firm of F. L. Smidth & Company, of New York, who made use of the experience gained by their wet installations in Europe.

Limestone Quarry of the Washington Portland Cement Company at Concrete.

Limestone and clay of the collowing ocmpositions are the raw materials used:

CLAY.		LIMEROCK.	
Loss on ignition	6.00%	Silica	2.00%
Silica	58.20%	Alumina	.66%
Alumina	18.17%	Iron	
Iron	6.95%	Calcium carbonate	96.04%
Lime	3.47%	Magnesium carbonate	.45%
Magnesia	3.28%	Undetermined	.85%
Undetermined	3.93%		

The limestone is brought from Balfour, a station on the Bellingham and Northern railway, about thirty-five miles from Bellingham, in gondola cars owned by the company, while the clay is shipped in from Brennan, five miles north of the plant, on the Great Northern.

At the quarry the machinery consists of a Fairmount crusher with a capacity of 600 tons an hour on 36 inch cubes. This feeds into a No. 6 Jumbo Williams mill through a special feeder which prevents too sudden a rush of material into the hammer mill; from the No. 6 the material feeds down to a 30 inch belt conveyor which carries it to the storage bins of 1,000 tons capacity. The tracks here are laid on a grade so that no shunting is necessary in loading. The clay pit is worked with a seventeen ton Industrial Works crane, which also does its own car switching.

Upon its arrival at the plant the material is run over a track scale to ascertain the weight and then unloaded into its respective storage. In the case of the clay this is done with a two yard bucket worked from an electric traveling crane; this same crane and bucket also drop the clay into the wash mill through a large wooden hopper. The rock is run up a 3 per cent. grade trestle by the company locomotive, a thirty-five ton, oil burning, four driver Vulcan dinky, into the top of the rock storage building, where the car bottoms are dropped, allowing the material to spill out.

The clay, after being thoroughly mixed with about 58 per cent. of water, is drawn from the agitating basin and elevated to the clay feeder above the kominuter bins by a two cylinder reciprocating back geared pump. The rock is brought

to the kominuter bins by belt and link belt pan conveyors. The clay and rock are first mixed when entering the kominuter, which are improved ball mills, together with sufficient water to give the required percentage. From the kominuters the material is elevated to the Trixes, which are wet separators returning the tailings to the kominuters and passing the screened materials to the No. 20 flint pebble tube mill, which acts as a preliminary grinder to two No. 18 tube mills. From there the slurry is conveyed to three correcting basins, the chemist checks the mixture and it is then passed into a large basin and well agitated. Owing to the fact that this basin is pumped out intermittently an air lift has been installed instead of a reciprocating pump, the apparatus being so arranged that by means of a tripper the same air, once compressed, is used continually on alternate tanks, with, of course, the addition of enough fresh air to make up for mechanical losses. This pumps the slurry to two large agitating basins below the kilns from which it is drawn by pumps and elevated to the feeder on the smoke chambers. These kilns, two in number, are 170 feet by 9 feet with a 10 foot diameter burning zone and are capable of turning out one thousand barrels each in twenty-four hours; burning is done with fuel oil vaporized by steam from a 125 H. P. Erie water tube boiler, the oil pumps and blowers being of the Korting, a German, make. The firing of the boiler is also done with oil. The clinker dropping from the kilns passes through a chute into double shell coolers which are not built upon a pitch, but depend upon castings to send the clinker forward; to these coolers are connected large fans which force a current of air through the cooler over the clinker thus cooling the clinker and heating the air which passes through the kilns, and part through the boiler draft in case it is wanted. The clinker is elevated to a portable belt conveyor over the clinker storage and is dumped either in the storage or in the clinker mill, the gypsum and clinker being weighed by hand before being dumped into the kominuter bins. Two No. 85 kominuters and two No. 18 combination flint and cylpeb

tube mills make up the grinding units in this building and are capable of grinding 2,000 barrels per day. A dust collector to take up the dust from the elevators and grinders has also been installed. It consists of a combination of a Cyclone dust collector and an automatic magnetically shaken filter with a suction fan placed at the end of the system.

ANALYSIS OF OLYMPIC PORTLAND CEMENT.

Silica	21.56
Alumina, Iron	9.82
Lime	63.94
Magnesia	1.30
Sulphur	1.19
Loss on ignition	1.41

The stock house consists of ten concrete silos 27 feet in diameter and 65 feet high with a total capacity of 100,000 barrels. These silos are fitted with six draw hoppers each, by means of which 82 per cent. of the material can be removed without shoveling, and beneath there are portable cross conveying machines, known as exbinners, which in turn discharge into a screw conveyor running the length of the silos. The packing house is equipped with four Bates packing machines feeding directly on to a belt which carries the bags into the cars; with this system, it is claimed, three men can pack and load 1,400 barrels per ten hour day.

Crude oil is used for fuel and there is a 55,000 barrel storage tank which is connected by pipe line to the company wharf, so that oil tank steamers may unload directly into the tank. This wharf has track laid upon it so that shipment may be made by water if it is desirable to do so.

The chemical laboratory is in the office building and is most modern in its appointments and equipment. There, as in the rest of the plant, no expense was spared to secure the best of everything and the results secured justify the outlay. The physical laboratory is in the basement together with the small crushers and pulverizers necessary in the sample work.

Electrical power is used in all departments from the hot plates in the chemical laboratory to the 250 H. P. motor driving the crusher, and the installation (the work of Mr. Viggo Sahmel, consulting electrical engineer for F. L. Smidth & Co.)

is without doubt the foremost of any in the cement manufacturing business. Absolute control of the mill is held at the switchboard, and numerous cutoff switches are so located that the man in charge of any machine may immediately shut it down without going to the panel board. The voltage, 2,200 for the higher powered machines and 220 for the smaller ones, has proven most efficient.

SKAGIT COUNTY.

Skagit county is south of Whatcom county and extends from Rosario Strait on the west to the summit of the Cascade mountains on the east. In its topographic features it is similar to Whatcom. The western part is low while the eastern is mountainous and very rough. In the western part of the county sedimentary deposits are common, while in the eastern igneous and metamorphic rocks are the predominating ones. Limestone, shale and clay are common in different parts of the county. The limestones occur best developed a little to the north and east of the central part of the county and are along the Skagit river. Clays also occur along the Skagit in close proximity to the limestones.

CONCRETE.

Concrete is on the Skagit river, 40 miles from its mouth, at the point where the Baker river empties into the Skagit. The Skagit branch of the Great Northern railway passes through the town and connects with the main line of the Seattle-Vancouver division at Burlington, about 28 miles west. This gives Concrete very good shipping facilities. Limestone, clay, and slate occur here and two cement plants have been built at this place and are in operation, using the limestone and clay.

Limestone.

The limestone deposits in this locality are in sections 1, 2 and 11, township 35 north, range 8 east and are north of the Skagit and east of the Baker river. The deposit where it is being quarried by the Washington Portland Cement Company, rises about 200 feet above the river and has a thickness of at least 150 feet. The general direction of the strike of the lime-

stone, as indicated by the slates which lie adjacent to it, is almost north and south, with a dip to the southwest. The limestone may be traced along the line of strike for a distance of about 650 feet, while a width of 250 feet is shown. The limestone shows practically no signs of stratification, appears fairly uniform in composition and texture, and is easily quarried.

Washington Portland Cement Company.—The limestone used by this company is quarried by what is known as the "Glory Hole" method. This consists in driving a tunnel into the deposit, starting low down on the side hill and then driving an opening to the surface. Through this tunnel cars are operated to haul out the limestone that is loaded into them, through the shaft connecting the surface with the end of the tunnel. The quarry is in the form of an inverted cone, the apex of the cone being in the shaft. In this way the limestone as it is quarried and broken up gradually works down to the lower end of the shaft and may be drawn off to fill the cars in the tunnel. From the bins near the month of the tunnel, the limestone is transported to the mill, a distance of one mile, by means of an aerial tram.

Laboratory Examination.—This limestone varies somewhat in color and ranges from very light to very dark. The larger part of it, however, is fairly light colored and when pulverized is almost pure white. The stone is coarse grained and fairly soft. If effervesces readily in cold dilute hydrochloric acid and is practically all dissolved.

The following analyses, furnished by the Washington Portland Cement Company, show the composition of the limestone in use at this plant:

ANALYSES OF LIMESTONE USED BY WASHINGTON PORTLAND CEMENT COMPANY, CONCRETE, SKAGIT COUNTY.

Silica (SiO_2)	5.36	4.26	5.56	2.06	4.68	6.76	3.72	8.36	2.92	8.40
Alumina and Iron (Al_2O_3, Fe_2O_3)	1.12	1.22	0.98	1.12	1.20	0.92	1.24	0.96	1.06	0.88
Lime (CaO)	52.08	52.70	51.98	54.25	52.30	51.20	53.22	50.70	53.60	50.30
Magnesia (MgO)	1.08	0.91	1.10	trace	0.92	1.16	0.62	1.04	trace	1.22
Calcium carbonate ($CaCO_3$)*	93.00	94.10	92.82	96.69	93.39	91.42	95.03	90.53	95.71	89.82

*Estimated from amount of lime (CaO) present.

The above analyses show this to be very low in magnesia and while it does not have quite as much lime as some it is a good grade of limestone.

Clay.

The clay used by the Washington Portland Cement Company occurs near the plant along the east bank of the Baker river. It occurs in large quantities at this place, but is not entirely uniform throughout the deposit, some of the layers being quite sandy. It shows well marked stratification, the different layers varying more or less in thickness. The face where this deposit is being worked shows a thickness of about 30 feet of clay. The deposit is exposed along the Baker river for more than 300 feet and extends up the Skagit river for more than one-half mile. The deposit is worked after the plan of a stone quarry. Beginning at the top it is worked in a series of benches. From the lowest bench the clay goes down a chute into small cars in which it is conveyed to the mill. The cars are drawn by an electric motor. The clay has to be carefully sorted as parts of the deposit are not fit for use. The stratification planes lie practically horizontal. This clay represents material that has been brought down and deposited by the Baker and the Skagit rivers.

The following chemical analyses show the composition of this clay:

ANALYSES OF CLAY FROM CONCRETE, SKAGIT COUNTY.
R. M. WHITE, Analyst.

Silica (SiO_2)	57.06	57.24	57.42	56.78	57.36	56.64
Alumina (Al_2O_3)	16.16	24.76	24.68	25.56	25.06	25.80
Iron (Fe_2O_3)	8.30					
Lime (CaO)	5.96	5.44	5.66	5.12	5.36	5.26
Magnesia (MgO)	3.20	4.86	4.58	4.30	4.56	4.26
Alkalies (Na_2O, K_2O)..	2.22	.....	.....	.....	.....	.....
Loss on ignition.....	6.22	.....	.....	.....	.....	.....

The above analyses show this clay to be a trifle low in sliica and a little high in iron and alumina. It also contains about 4½ per cent of magnesia, which is above the average. The limestone with which it is mixed, however, is practically

free from this substance and the amount in the cement is still considerable below the maximum allowed.

Description of the Plant.—The materials used by the Washington Portland Cement Company consist of limestone and clay. The limestone is quarried on the deposit located about one mile from the works, being quarried by the Glory Hole system, and delivered to the crushing plant located at the quarry, where it is reduced by No. 6 Gates crushers to a size, the largest of which would pass a 5 inch ring. The storage capacity for crushed rock at this point is sufficient to handle 2,500 tons. From here the crushed rock is delivered to the mill on an aerial tramway, at the lower terminals of which are located bins holding approximately 1,500 tons. From this latter rock storage the rock is delivered to No. 4 Gates crusher, where it is reduced to about 1 inch ring. Leaving the crushers, the rock passes through rotary dryers, then to ball mills, where it is reduced so that all material will pass a 12 mesh screen. From the ball mills the ground rock is transported to the mixing bins, where sufficient storage is kept for about three days operation. The storage up to this point giving sufficient rock on hand so that analyses can be made from which the mixture is calculated.

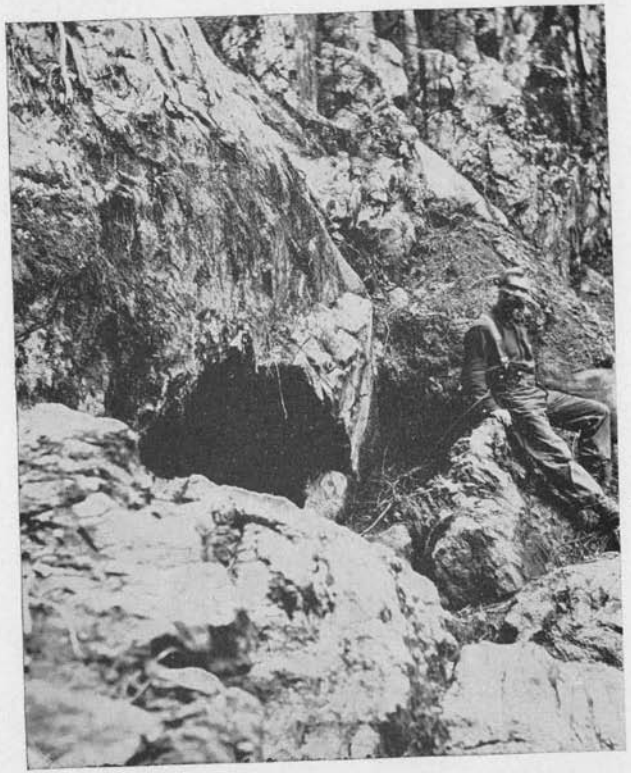
The clay is located about one-quarter of a mile from the plant and is delivered by means of an electric railway. Sufficient storage is provided at the mill to house three months' supply of clay, so that the quarry will not have to be operated in extreme bad weather. The clay from storage is delivered to a clay crusher by means of conveyor belts, and from the crusher is taken to rotary dryers and from this point to the mixing bins, where sufficient storage is provided in ratio with the rock. From the mixing bins the dried and powdered limestone and clay are conveyed to automatic weighing machines, which are set to compound the correct mixture as determined by analyses. From the mixing scales the material is mixed thoroughly through a double cut flight conveyor, the mixed materials then being stored in bins located at the heads of the

tube mills, through which the material passes and is ground so that 97 per cent will pass a screen having 100 openings to the square inch. The material termed raw flour passes to the kiln bins and is ready to be burned. In the kilns the chemical combination of the limestone and clay is effected, the result being the clinker of Portland cement. This clinker is conveyed mechanically to a storage with a capacity of about 200,000 barrels, arrangements being made so that the clinker can be distributed at any point in the storage, thus making is possible to grind the older clinker first. The clinker from the storage is handled mechanically to a dryer, then weighed and mixed with gypsum and transported to the grinding mills, the first reduction being made through Sturtevent ring roll mills and ball mills, and the final reduction through tube mills, a degree of fineness being obtained so that 98 per cent. of the cement passes through a 100 mesh sieve and 88 per cent. through a 200 mesh sieve. From the finishing mills the cement is conveyed and stored in a stock house divided into ten bins, each bin having a capacity of about 7,000 barrels. From these bins the cement is conveyed mechanically and packed in bags by means of automatic scales.

A thorough system of checking, both of chemical and of physical properties, of the raw material and the cement is maintained day and night, a complete set of records being kept upon every hour's output and an average output for each day.

Superior Portland Cement Company.—The materials used by this company are limestone and clay and are very similar to those used by the Washington Portland Cement Company. The limestone quarry is about two miles from the plant and connected with it by a railroad over which the limestone is transported. The quarry is worked by what is known as the "Glory Hole" method. The limestone averages about 90 per cent. carbonate of lime.

Description of the Plant.—The plant is supplied with three kilns 7½ feet in diameter and 125 feet long and one kiln 8 feet in diameter and 135 feet long. The raw materials are



A. Entrance to Limestone Cave, 400 feet above Jackman Creek, in Section 4, Township 35 North, Range 9 East, Skagit County.

B. Cliff of Limestone on the Divide between Weber and Medberry Creeks, near Van Horn, Skagit County.

pulverized on Williams and ball mills, the fine grinding being done by four tube mills, each 6 feet in diameter and 22 feet long. On the finished side for the clinker the grinding is done by three Sturtevant ring roll mills and six tube mills, each 6 feet in diameter and 22 feet long. All of the tube mills are equipped with a Cylpeb installation, which is claimed to increase the output of each mill about 30 per cent.

The storage capacity is about 85,000 barrels and the daily capacity of the plant about 2,200 barrels. The packing room is equipped with three Bates automatic sacking machines, giving a packing capacity of 3,000 barrels in ten hours.

The fuel used in the burning of the cement at this plant is crude oil and electric power is used for driving the machinery.

JACKMAN CREEK.

This is a small stream that empties into the Skagit river about two miles above the mouth of the Baker river. Limestone and clay deposits occur in places along this creek.

Limestone.

The limestone examined is in sections 4, 5, 8, and 9, township 35 north, range 9 east, and is up the creek from its mouth about four miles, and in sections 35 and 36, township 36 north, range 9 east, about two and one-half miles up Jackman creek from the other deposit. These deposits are very large, as they cover a large area, and exposures were seen where the limestone is at least 75 feet thick. The deposits vary more or less in color, in some places being very light, while in others they are dark gray.

Laboratory Examination.—This limestone is crystalline in character and very uniform in texture. Much of it has many seams of coarsely, crystalline white calcite running through it. There are also some places where it has a slightly cherty appearance and where it is harder than it is in other places. Taken as a whole, the rock has only a medium hardness and is easily pulverized. The powder is almost pure white in color and,

when treated with cold dilute hydrochloric acid, it is readily dissolved.

The following analyses show the chemical composition of this limestone:

ANALYSES OF LIMESTONE FROM JACKMAN CREEK, SKAGIT COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	1.94	3.36
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.22	1.78
Lime (CaO)	54.92	51.85
Magnesia (MgO)	trace	0.30
Loss on ignition	42.67	42.61
Total	99.75	99.90
Calcium carbonate ($CaCO_3$)	98.07	92.59

I. From deposits in Secs. 4, 5, 8, and 9, T. 35 N., R. 9 E.
II. From deposits in Secs. 35 and 36, T. 36 N., R. 9 E.

The above analyses show either of these samples to be good limestone. They are each of them practically free from magnesia and contain a good percentage of lime, number one having an especially large amount. Number two has some silica but this would not injure it for Portland cement, except that it would make it harder to grind.

Clay.

Clay in apparently large quantities occurs along Jackman Creek about two miles from its mouth. The clay is well stratified, lies in practically horizontal beds, and represents silt that has been brought down and deposited by the stream. The deposits, where they have been exposed, appear to be very uniform and free from sandy layers.

Laboratory Examination.—This clay is very fine grained and entirely free from gritty particles of any kind. It absorbs water and slakes quickly, breaking into a mass of very thin flaky particles. This clay is light gray in color when dry, but has a slightly bluish tinge when wet.

The following analyses show the chemical composition of this clay:

ANALYSES OF CLAY FROM JACKMAN CREEK, SKAGIT COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	60.21	54.18
Alumina (Al_2O_3)	16.21	18.05
Iron (Fe_2O_3)	5.10	9.91
Lime (CaO)	2.90	4.17
Magnesia (MgO)	4.15	4.51
Potash (K_2O)	2.10	1.17
Soda (Na_2O)	1.51	1.04
Loss on ignition	7.10	6.98
Total	99.26	100.01

The above analyses show a slight difference in the composition of the two samples. Number one is the better clay as it has more silica and less alumina and iron, and this gives a better ratio between these substances. Either of them, however, has a rather high percentage of magnesia. In number two the amount of silica is quite low, especially when compared with the amount of iron and alumina that it contains. Either of these samples have good physical properties and number one is a good clay to be used in the manufacture of Portland cement, with a limestone low in magnesia. Number two would be good also, providing a small amount of a more siliceous material were mixed with it.

Forturnately, the limestone in this locality has practically no magnesia in it and is a fine material to use with this clay, and a good Portland cement should be made from the mixture.

SAUK.

Sauk is a station on the Skagit branch of the Great Northern railway. It is on the Skagit river where the Sauk river empties into it and about six miles east of Baker. It is a small shingle mill settlement of about 70 inhabitants. Limestone and clay occur in the hills to the north and west from one to three miles.

Limestone.

The limestone in this locality is very similar in general appearance to that on Jackman creek. The limestone in this lo-

cality is mainly in sections 9, 15 and 16, township 35 north, range 9 east and the deposits have been located and some development work done. From the Skagit river the hills rise quite abruptly and an altitude is reached on some of these claims of more than 3,000 feet above sea level or about 2,800 feet above the river. In places limestone is exposed in perpendicular cliffs as much as 100 feet high and extending horizontally for from 400 to 600 feet. The deposits show very little signs of stratification and are quite coarse in texture.

Laboratory Examination.—In color this limestone varies from a dark gray to mottled white and when pulverized it is almost pure white. It is fairly soft, pulverizes easily, and is readily dissolved in cold dilute hydrochloric acid. The samples collected from this locality have in places a glassy appearance.

The following analysis shows the chemical composition of the limestone from this locality:

ANALYSIS OF LIMESTONE FROM SAUK, SKAGIT COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	1.36
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.82
Lime (CaO)	54.77
Magnesia (MgO)	trace
Loss on ignition	42.05
Total	99.00
Calcium carbonate ($CaCO_3$)	97.80

The above analysis shows this to be a very high grade limestone and very similar to the deposits on Jackman creek, some of which are not more than one mile from it.

Clay.

Clay is very common in the vicinity of Sauk. About 200 feet above the Skagit river at this point is a more or less rolling bench, with a width in places at least, of more than 500 feet. Open cuts and tunnels have disclosed the fact that this bench, which extends along the foot of the mountains for more than a mile, contains large bodies of clay. In places this clay is known to have a thickness of more than 40 feet. The deposits, where they have been exposed to this depth, are very uniform in composition from top to bottom, with practically no sandy layers showing. This clay is distinctly stratified and represents ma-

terial that has been deposited by the Skagit river. Undoubtedly this clay occurs in large quantities in this locality.

Laboratory Examination.—When wet this clay has a bluish color and when dry is light gray in color. It is very fine grained, entirely free from gritty material, and slakes readily when brought in contact with water, breaking into a mass of small, very thin flakes. It becomes quite hard when dried but would not be hard to pulverize because of its being so very fine grained.

The following analysis shows the chemical composition of this clay:

ANALYSIS OF CLAY FROM SAUK, SKAGIT COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	56.18
Alumina (Al_2O_3)	17.37
Iron (Fe_2O_3)	8.89
Lime (CaO)	4.14
Magnesia (MgO)	4.60
Potash (K_2O)	1.76
Soda (Na_2O)	1.43
Loss on ignition	5.03
Total	99.40

This clay, as shown by the above analysis, is a little low in silica and alumina and high in iron and magnesia. The ratio between the silica and the iron and alumina is low, the amount of silica being only a trifle more than twice that of the sum of the other two. The amount of magnesium oxide is equivalent to 9.66 per cent. of magnesium carbonate ($MgCO_3$) and this would prevent the use of this clay with any limestone except where it contains only a small amount of magnesia. This clay has especially good physical properties, however, and the limestone in this same locality has practically no magnesia, so that these two might be used together in the manufacture of Portland cement. If a more highly siliceous material could be found in this locality and a small amount of this used with the limestone and clay, better results could be obtained.

ROCKPORT.

Limestone.

Rockport is the eastern terminus of the Skagit branch of the Great Northern railway and almost due east of Sauk about two miles. Limestone occurs about one mile north of town and

is exposed best along a small creek. It extends along the creek for about 800 feet and a thickness of more than 120 feet is shown in places. The deposits are massive and in the main rather dark gray in color. Several bodies of limestone are found to the northeast of Rockport, between there and Marblemount, but none of these were examined. They are, however, in all probability similar to those around Sauk and Rockport.

Laboratory Examination.—Some samples of this limestone show considerable amounts of coarsely crystalline white calcite occurring in them, while others are very uniform throughout in color and texture. In the main this stone is finely crystalline, medium in hardness and pulverizes easily, the powder being almost pure white in color. It is readily soluble in cold dilute acids with rapid effervescence.

The following analysis shows the chemical composition of this limestone:

ANALYSIS OF LIMESTONE FROM ROCKPORT, SKAGIT COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	0.78
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.72
Lime (CaO)	54.95
Magnesia (MgO)	trace
Loss on ignition	43.50
Total	99.95
Calcium carbonate ($CaCO_3$)	98.12

The above analysis shows this to be an especially high grade limestone almost free from impurities of all kinds.

SNOHOMISH COUNTY.

Snohomish county is situated between King county on the south and Skagit county on the north and extends from the waters of Puget Sound on the west to the summit of the Cascade mountains on the east. In altitude it varies from sea level to 10,436 feet above, the highest point being Glacier Peak. The eastern part of the county is very rough and mountainous. Through this part of the county igneous rocks, such as granites, diorites and rocks of this general type predominate.

GRANITE FALLS.

Limestone.

Granite Falls is a small town situated about fifteen miles northeast of Everett on the Everett and Monte Cristo railroad,

which is now a branch of the Northern Pacific railway. Two limestone deposits are found a few miles east and north of the town, and another one about twenty-five miles east and north, at the western base of Liberty Peak on Bopeep creek, which is a stream flowing into Canyon creek. In each of these places the extent of the deposit is not very great. One of these bodies is in sections 5 and 8, township 30 north, range 7 east and has

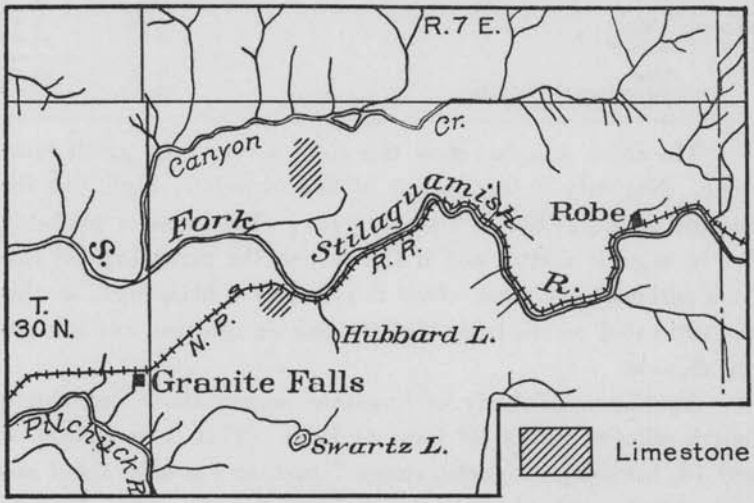


FIG. 10. Limestone deposits near Granite Falls, Snohomish County.

been developed somewhat with the view of burning lime. This limestone occurs on the south and east side of a hill which rises to a height of more than 200 feet above Canyon creek. This deposit does not cover a very large area and lies high up on this hill so the deposit is not an especially large one. The limestone lies in contact with and on a dark basic igneous rock and shows very little sign of stratification.

Laboratory Examination.—The limestone is dark gray in color and rather coarsely crystalline. When pulverized it is light gray and when treated with dilute hydrochloric acid effervesces rapidly and dissolves with the exception of a very small amount of dark colored sediment.

The following analyses show the chemical composition of this limestone:

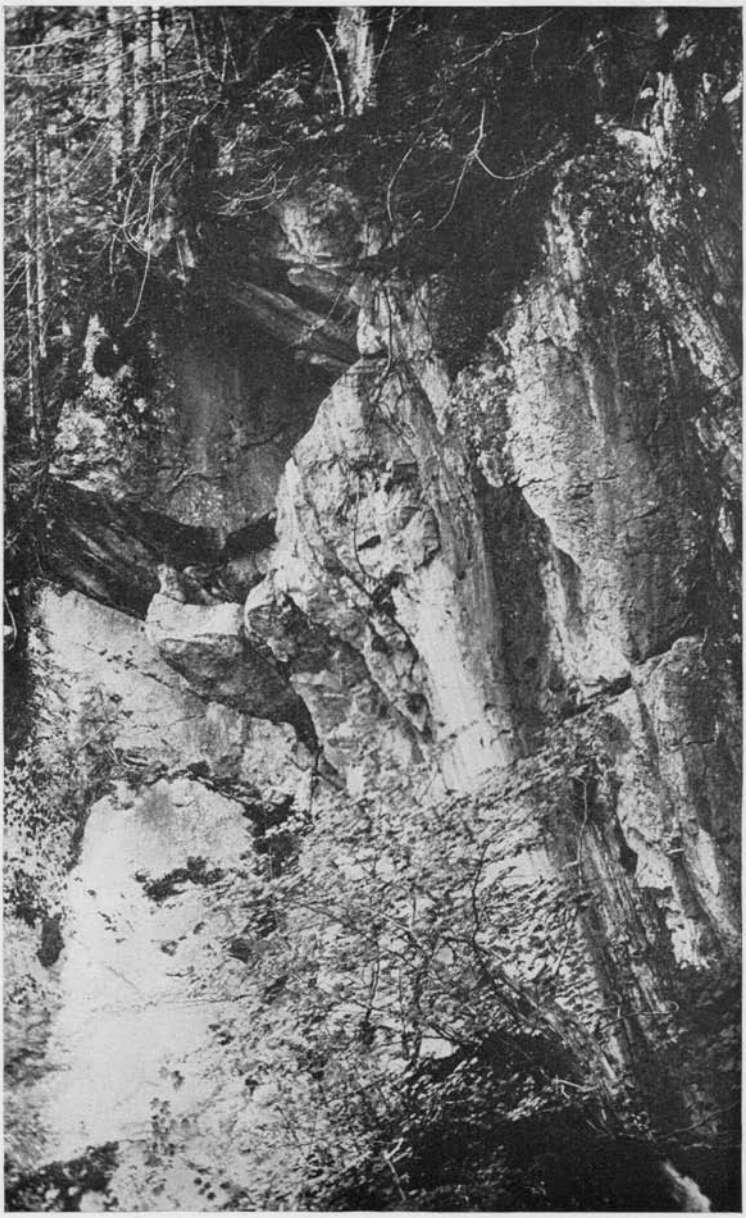
ANALYSES OF LIMESTONE TWO AND ONE-HALF MILES NORTHEAST OF GRANITE FALLS, SNOHOMISH COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	0.22	0.61
Alumina and Iron (Al_2O_3, Fe_2O_3)	trace	0.13
Lime (CaO)	55.12	54.44
Magnesia (MgO)	trace	0.42
Loss on ignition	43.86	44.00
Total	99.20	99.60
Calcium carbonate ($CaCO_3$)	98.43	97.22

The above analyses show this to be a very high grade limestone. Not only is the amount of lime especially high, but the amount of impurities is also very low. The color is probably due to organic matter and if this is true the percentage of calcium carbonate as given above is probably a little high, as this was estimated on the basis that the loss on ignition was all carbon dioxide.

Another small body of limestone occurs about one and a fourth miles northeast of Granite Falls. This is in sections 8 and 13, township 30 north, range 7 east, and is only about one mile almost south of the body on Canyon creek. The Everett and Monte Cristo railroad passes right by this deposit and a considerable amount of this limestone has been shipped to Everett and used as a flux in the smelter which is located there.

The deposit appears to cover only a small area on the north side of the hill wihch rises about 500 feet above the railroad. The limestone, however, does not extend more than about 50 feet above the railroad. In color it is dark gray with streaks of white through it. It is finer grained than that described above, the darker part of it having a somewhat flinty appearance. When pulverized this limestone is dark gray in color, effervesces rapidly when treated with dilute hydrochloric acid and leaves a small amount of insoluble residue. No analyses of this limestone were made, but in all probability it has a good percentage of lime.



Cliffs of Limestone on Weber Creek, Skagit County, in Section 4, Township 35 North, Range 9 East.

The limestone on Bopeep creek occurs closely associated with igneous rocks, and as far as could be determined, is very limited in extent. This deposit shows well marked stratification, the individual layers having a thickness in some cases of several feet. In color this limestone is light gray as a result of the occurrence, in a more or less banded condition, of very light and very dark colored materials. In texture it is finely crystalline.

In cold dilute hydrochloric acid it effervesces quite rapidly and dissolves with the exception of a very small amount of an almost black substance. Samples of this limestone were not analyzed and so its composition is not known.

Clay occurs just across Canyon creek from the limestone and distant from it about one-half mile. It occurs along the south bank of Canyon creek and appears to be quite extensive. It is blue in color when wet and light gray when dry. It is fine grained and free from gritty material. The deposit appears to be very free from sandy layers and uniform in composition.

INDEX.

Clay.

Index is on the main line of the Great Northern railway, near the southern line of Snohomish county, and is about six miles northwest of Baring, King county, where some good limestone occurs. About two miles up the river from Index clays were found exposed in a cut along the railroad. This material was exposed for a distance of 300 feet and to a depth, in the deepest place, of 15 feet. In no place, however, was the bottom of the deposit exposed, so it may be much thicker. The clay is finely stratified and appears to be very uniform in composition, no sandy layers being noticeable. When wet it is blue in color and when dry light gray.

Laboratory Examination.—This clay is very fine grained and entirely free from gritty materials of any kind. It absorbs water rapidly and slakes breaking into a mass of thin flakes. It consists of very minute grains that are slightly greenish in color and quite uniform in size. Most of the grains are fairly well rounded, very few having sharp edges or angles. When mixed

with water this clay has fair plasticity and when dry is hard and flinty.

The following analysis shows the chemical composition of this clay:

ANALYSIS OF CLAY FROM NEAR INDEX, SNOHOMISH COUNTY.
A. A. HAMMER, Analyst.

Silica (SiO_2)	53.56
Alumina (Al_2O_3)	25.26
Iron (Fe_2O_3)	8.86
Lime (CaO)	2.66
Magnesia (MgO)	2.05
Potash (K_2O)	0.43
Soda (Na_2O)	0.27
Loss on ignition	6.02
Total	99.11

This clay has a very small amount of silica as compared with the amount of alumina and iron and from the chemical analyses it appears it would not be a very satisfactory material to use in the manufacture of Portland cement unless some highly siliceous material were mixed with it.

KING COUNTY.

King county is just south of Snohomish county and in its topographic features is very similar to it. The eastern part of the county is very rough and mountainous and consists mainly of igneous rocks of one kind or another. Limestones are known to occur, however, near Baring and at Snoqualmie Pass, and clay and shale at many places.

BARING.

This is a station on the main line of the Great Northern railway almost at the northern edge of the county, a little east of its center. It is in the canyon of the south fork of the Skykomish river, about six miles southeast of Index and is surrounded by high mountains.

Limestone.

About two miles up the Skykomish river from Baring and about one-half a mile south of the stream are some limestone deposits. These are in sections 24 and 25, township 26 north, range 10 east. They begin about 500 feet above the river and outcrop in various places from there to the summit of the mountain, a distance of about one and a half miles. Some of the out-

crops show exposures of limestone more than 100 feet thick, extending along the face of the mountain as much as 3,000 feet. Several claims have been located on these deposits and some development work done so as to expose the deposits in places. The dense vegetation in this locality makes it very difficult to trace these deposits on the surface and the development work done so far has not been sufficient to determine their extent, so that but little can be said on this point. The indications are, nevertheless, that there is quite a large body of this limestone.

The stone varies more or less in color and ranges from an almost pure white to a dark blue. It is stratified more or less in some places, but nowhere is this very marked.

Laboratory Examination.—This limestone is very fine grained and when pulverized is almost pure white in color. When treated with dilute hydrochloric acid it effervesces very rapidly and is practically all dissolved. It has a medium degree of hardness for limestone, is slightly brittle and pulverizes very easily.

The following chemical analyses show the composition of this limestone:

ANALYSES OF LIMESTONE FROM BARING, KING COUNTY.
A. A. HAMMER, Analyst.

CONSTITUENTS.	I.	II.
Silica (SiO_2)	0.40	2.64
Alumina and Iron (Al_2O_3, Fe_2O_3)	0.16	1.52
Lime (CaO)	53.30	53.38
Magnesia (MgO)	1.98	1.30
Loss on ignition	43.86	40.92
Total	99.70	99.76
Calcium carbonate ($CaCO_3$)	95.18	95.32

I. White, finely crystalline.
II. Dark gray, finely crystalline.

The two samples are practically the same in composition, except as regards the silica. The analyses show this to be a high grade limestone. It has a very high percentage of lime as well as good physical properties and is a good Portland cement material. The main thing to be determined is the quantity.

CHAPTER IX.

POSSIBILITIES OF THE CEMENT INDUSTRY IN WASHINGTON.

Materials from which cement may be made are found only in certain parts of Washington. In some cases the limestone and clay or shale occur in close proximity while in others they are long distances apart and one or the other of them would have to be transported. In some cases also the materials are not well situated as regards transportation and this would have to be supplied.

Limestone.

The limestone of Washington is mainly in the northern part of the state, the most important deposits occurring in San Juan, Whatcom, Okanogan, Ferry, Stevens, Chelan, Pend Oreille, Skagit, Snohomish, and King counties. The general tendency of the limestone throughout Washington is to occur in isolated masses covering comparatively small areas. In the northeastern part of Washington, especially in Pend Oreille and Stevens counties, the limestone areas are the most extensive and in this locality some of the bodies are quite large.

Practically all of the limestone has been more or less metamorphosed and in many cases would be considered a marble. In most cases the deposits show no stratification. Very few fossils have been found in them and their age has not been determined. In color they vary much, some of them being pure white, while others are almost black. The prevailing color, however, is either gray or a mixture of gray and white.

In composition the limestones of Washington vary much and range from very pure calcium carbonate to those in which there is but little calcium present. The most common impurity in these limestones, especially those in eastern Washington, is magnesia and in some cases this predominates and only a very small amount of calcium is present.

The following analyses taken from Vol. II, Washington

Geological Survey, show the large amount of magnesia in some of the Washington limestones:*

ANALYSES OF LIMESTONES FROM STEVENS COUNTY, WASHINGTON.
R. W. THATCHER, Analyst.

CONSTITUENTS.	I.	II.	III.	IV.	V.	V.
Silica (SiO_2)	5.79	0.91	0.89	18.18	1.89	2.94
Alumina (Al_2O_3)	0.43	none	none	0.44	none	0.49
Ferric oxide (Fe_2O_3)...	0.85	none	none	0.45	none	0.49
Ferrous oxide (FeO)...	none	none	0.58	1.17	trace	trace
Lime (CaO)	1.69	31.80	none	24.74	42.60	31.56
Magnesia (MgO)	42.07	20.68	45.76	16.10	10.05	18.56
Carbon dioxide (Co_2)..	47.23	46.64	49.24	38.18	44.63	45.91
Water (H_2O) at 110°..	.....	.....	.....	0.05	.....	trace
Water (H_2O) above 110° and undetermined substances	1.94	none	3.53	0.69	.....	trace
Total.....	100.00	100.03	100.00	100.00	100.17	99.95

I. Black marble from near Valley.
II. White marble from near Colville.
III. Pink marble from near Valley.
IV. Pink marble from near Valley.
V. Dark gray marble from near Colville.
VI. White marble from near Bossburg.

The above analyses are given to show the large amount of magnesia that occurs in some of the limestones in Washington. It is not to be inferred, however, from these analyses that all of the limestones in Washington contain large amounts of this substance, as they do not. In some cases the limestone is practically free from magnesia, while in others it contains but a very small amount. Limestone coming from certain parts of the state is very likely to contain more or less magnesia and if it is desired as a material for use in the manufacture of Portland cement it should be given a very thorough examination to determine whether or not this substance is present in any large amount. In many places the limestones are well suited as materials from which to manufacture Portland cement.

ASOTIN COUNTY.

At Lime Hill, in Asotin county, limestone occurs. This is very free from magnesia, and might be used in the manufacture of Portland cement.

*Shedd, Building and Ornamental Stones of Washington, Washington Geological Survey, Vol. II, 1902, p. 142.

PEND OREILLE COUNTY.

In this county large deposits of limestone occur at Cement, Metaline Falls and along the Pend Oreille river to the north. The analyses of these limestones show that they vary somewhat in composition. The samples from Cement are usually low in magnesia, but in one case as high as 12.4 per cent is shown. The analyses all show a considerable amount of silica, in one case being as high as 26.04 per cent. The deposits at Metaline Falls are of good quality, being high in lime and low in magnesia.

STEVENS COUNTY.

This county contains the largest limestone deposits in Washington. As already shown, some of the limestones in this county are very high in magnesia and of no value for Portland cement. In some localities, however, they are very low in magnesia. A very thorough sampling and a large number of analyses should be made before deciding to use any one of these deposits. Near Valley, at Jump Off Joe lake, a small area of very good limestone occurs. About one mile south of Colville is a limestone deposit that is low in magnesia and that has from about 80 to as high as 95.52 per cent. of calcium carbonate. The indications are that this might be used in the manufacture of Portland cement. Limestones of good quality are found in places along Mill creek and Clugston creek. A short distance south of Kettle Falls limestone occurs that is very low in magnesia and almost free from other impurities. In Peaceful Valley, about seven miles south of Kettle Falls, are some good sized bodies of very high grade limestone that are especially well suited for Portland cement. In the vicinity of Evans, Bossburg, Ryan, Northport, and in places along Deep Creek large deposits of very high grade limestone are found from which good Portland cement may be made.

The above are some, at least, of the places in Stevens county where good limestones occur. The deposits in many parts of the county have not been thoroughly sampled and in all probability many other good deposits may be found. Even in the places mentioned above, however, a very thorough examination

should be made before going to the expense of building a plant with a view to using any of these deposits in the manufacture of Portland cement.

FERRY COUNTY.

In Ferry county only a very few bodies of limestone are found and these, with the exception of the one a few miles west of Orient, are all small.

OKANOGAN COUNTY.

Limestone is found in several places in Okanogan county, the largest deposits being in the vicinity of Chesaw and Riverside. The samples that were analyzed from the Chesaw deposits are very pure limestone and indicate that the deposits are high grade. The Riverside deposits, however, are far from uniform, in places being almost free from magnesia, while some samples have as high as 47.53 per cent. of magnesium oxide (MgO). In places these are also high in silica and are flinty in character.

CHELAN COUNTY.

In Chelan county limestone occurs a few miles north of Wenatchee and in places along the shores of Lake Chelan, and the analyses of samples from these different localities show the limestone in each case to be of good quality.

In the western part of Washington the various limestone bodies are not as a general thing so large as those in the eastern part of the state. They are, however, in the main, of better quality as they carry less impurities.

WHATCOM COUNTY.

Limestones occur in Whatcom county in the vicinity of Kendall and Maple Falls. The analyses show these deposits to be high grade lime. Some of the bodies, however, are not very large.

SAN JUAN COUNTY.

Limestones occur in a number of places on some of the islands in this county. On San Juan island a large body of limestone occurs and this is being used by the Roche Harbor Lime Co. in the manufacture of lime. A number of separate bodies of limestone occur on Orcas island and some lime is being burned

from them. The analyses show these deposits to be a good grade of limestone.

SKAGIT COUNTY.

Limestone is quite common in Skagit county. It is found at Concrete and near Sauk, Rockport, and along Jackman creek. These are among the largest limestone bodies in western Washington and the analyses show them all to be of good quality and two Portland cement plants have been built and are using the limestone that occurs near Concrete. The deposits along Jackman creek and in the vicinity of Sauk are also very promising.

SNOHOMISH COUNTY.

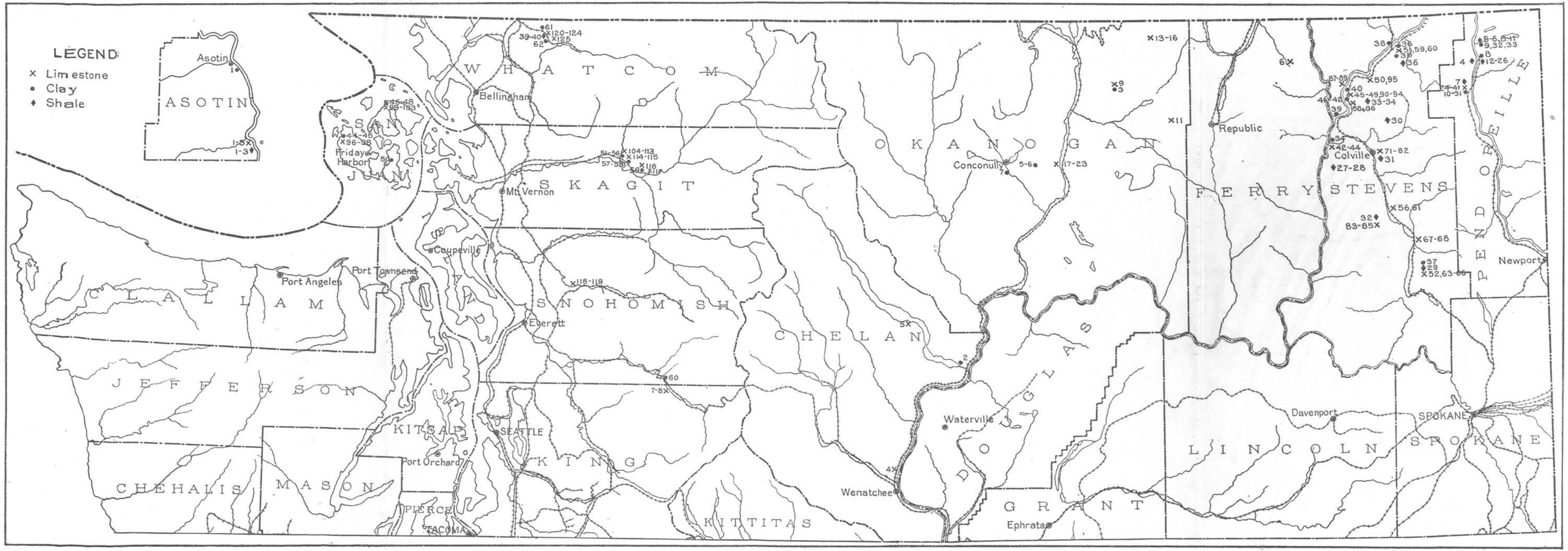
In this county some high grade limestone occurs but the indications are that there is only a small amount of it.

KING COUNTY.

Limestone occurs near Baring, in King county, and the analyses show it to be of good quality, but little is known in regard to the quantity that occurs at this place. Limestone is also known to occur at Snoqualmie Pass in this county, but I do not know anything as regards the quality or the quantity of these deposits.

Clays of Washington.

Clays are widely distributed throughout the state of Washington, there being few localities where they do not occur. The clays which occur in the different parts of the state, however, vary much in composition, color, and physical properties, due to the fact that the formations from which they have been produced by weathering are different in the different localities. In many instances the composition of the clay is such as would make it a very desirable material for use in the manufacture of Portland cement. As already shown, clay to be of value for this purpose must have a certain ratio existing between the silica and the alumina and iron. In clays that are suited to the manufacture of the better grades of clay wares the amount of alumina is so high that they are not of value for Portland cement. Large deposits of clay occur around Clayton, in Stevens county, but much of it is so high in alumina as compared with the silica that it has no value for Portland cement.



Map of a part of Washington, showing the localities where samples of Limestone, Clay and Shale were collected for analyses. The numbers on the map correspond to the numbers of the samples in the tables of analyses.

In that part of eastern Washington where the limestones are most abundant good clays are not so abundant as they are in some other parts of Washington. In places, however, they do occur and some of them are well suited for cement. In the northern part of western Washington glacial clays are very common and in some places large deposits of fine grained blue colored clays are found along the streams. In the limestone areas of western Washington clays are very common. Good clays for use in the manufacture of cement are found in San Juan, Whatsom, Skagit, and King counties in close proximity to the limestones. Such clays are also very common in practically all of the other counties of western Washington, so that there is no lack of good clay for the manufacture of Portland cement.

For a fuller discussion of the clays of Washington see "Clays of the State of Washington, Their Geology, Mineralogy, and Technology" by S. Shedd, published by the State College, Pullman, Washington.

The following analyses show the composition of clays that are being used in the manufacture of Portland cement by some of the best known Portland cement manufacturers:*

ANALYSES OF CLAYS USED FOR THE MANUFACTURE OF PORTLAND CEMENT.

CONSTITUENTS.	I.	II.	III.	IV.	V.	V.
Silica (SiO_2)	61.09	63.75	52.00	61.92	55.27	58.44
Alumina (Al_2O_3)	19.19	16.40	17.00	16.58	28.15	18.95
Iron (Fe_2O_3)	6.78	6.35	5.00	7.28		7.55
Lime (CaO)	2.51	2.40	20.00	2.01	5.84	1.70
Magnesia (MgO)	0.65	1.42	.....	1.58	2.25	1.88
Sulphur (So_3)	1.42	0.14	1.00	trace	0.12	.....
Loss on ignition	5.13	6.89	3.20	.....	.....	9.07
Used with	Lime-stone	Marl	Marl	Lime-stone	Lime-stone	Lime-stone

I. Alpena Portland Cement Co., Alpena, Michigan.
II. Bronson Portland Cement Co., Bronson, Michigan.
III. Buckeye Portland Cement Co., Harper, Ohio.
IV. Catskill Cement Co., Smith's Landing, New York.
V. Glens Falls Portland Cement Co., Glens Falls, New York.
VI. Pacific Portland Cement Co., Suisun, California.

*Meade, Portland Cement, Its Composition, Raw Materials, Testing and Analysis, p. 45.

Shales.

Shales are very common in many parts of Washington. In the northeastern part of the state they occur quite widely distributed throughout the metamorphic area and in western Washington they are very common in connection with the coal formations in that part of the state. While the shales have been examined but little, and few analyses made, there are undoubtedly large deposits of this material that is especially well adapted for use in the manufacture of Portland cement and especially when they are found in limestone districts a very careful examination of the deposits should be made to determine their extent and if found in quantity they should be carefully analyzed. The shales in Washington should prove one of our valuable Portland cement materials.

CONCLUSIONS.

The demand in Washington for Portland cement is constantly increasing and should continue to increase as time goes on. As states become older and more developed the demand becomes greater for better and more permanent improvements. Washington has been well supplied with large quantities of very fine timber from which especially good lumber could be manufactured and this has been used very extensively for building and other purposes. Lumber, however, is becoming more expensive all the time and a point will eventually be reached where, if permanence is considered, some other kind of material will take its place for many purposes. In the eastern part of Washington, especially where timber is scarce, Portland cement should find a very large use in the country as well as in the cities. It may be used on the farm for many purposes where lumber has in the past been used exclusively. Some of its most important uses on the farm at the present time are for posts, troughs, tanks, dams, walls, steps and stairs, sidewalks, curbs, and gutters, floors, silos, cisterns, cellars, and culverts.

In western Washington the cities are using a large amount of Portland cement, and this is growing all the time. Washington has a very large number of favorable opportunities for

water power development and large amounts of Portland cement will be used for this purpose.

At the present time much of the cement used in this state is shipped into it and with the materials that Washington has from which to manufacture first class Portland cement this should not be the case. The industry in this state, however, is only six years old and in that time has grown so that the present capacity (May, 1913) of the five mills that are being operated and the one that is being built, is approximately 10,000 barrels per day. There are splendid opportuities for greater development of this industry and the outlook for the future is very promising.

APPENDIX A.

Table of Chemical Analyses of Washington Limestones, Clays and Shales.

LIMESTONES.

ASOTIN COUNTY.

No.	Nearest Town.	LOCATION.	CHARACTER OF MATERIALS.	SiO_2	R_2O_3	CaO	MgO	$CaCO_3$	$MgCO_3$	Loss	Total
1	Anatone.....	Lime Hill, near basalt.....	Gray, decomposed, slaty.....	5.98	2.08	51.07	0.78	91.19	1.91	39.93	99.98[1]
2	Anatone.....	Lime Hill, near summit.....	Gray, fine textured, slaty.....	6.10	2.16	50.06	0.68	89.39	1.70	39.60	99.60[1]
3	Anatone.....	Lime Hill, near exposure.....	Gray, fine weathered, slaty.....	5.48	3.50	49.90	0.65	89.10	1.62	39.20	98.82[1]

CHELAN COUNTY.

4	Wenatchee.....	Five miles north.....	Fine grained, almost white.....	0.38	0.21	55.26	none	98.68	none	43.98	99.83[1]
5	Lakeside.....	Sec. 13, T. 29 N., R. 20 E.....	Medium texture, white.....	2.40	trace	53.28	0.65	95.14	1.36	43.26	99.59[1]

FERRY COUNTY.

6	Orient.....	In hills to west.....	Coarse texture, white.....	4.65	0.99	31.96	19.31	.....	.....	43.54	100.45[1]

KING COUNTY.

7	Baring.....	Secs. 24 and 25, T. 26 N., R. 10 E.....	Fnely crystalline, white.....	0.40	0.16	53.30	1.98	95.18	4.16	43.86	99.07[1]
8	Baring.....	Secs. 24 and 25, T. 26 N., R. 10 E.....	Finely crystalline, dark gray.....	2.64	1.52	53.38	1.30	95.32	2.73	40.92	99.76[1]

OKANOGAN COUNTY.

9	Havilla.....	East one-half mile.....	Finely crystalline, blue.....	1.80	0.60	54.62	trace	97.53	trace	41.88	98.90[1]
10	Van Slyke.....	North one mile.....	Crystalline, white.....	3.64	2.18	49.36	2.83	88.15	5.94	39.28	97.27[1]
11	Republic.....	Granite Creek	Schistose, white to blue.....	9.10	4.10	48.16	3.16	85.72	6.64	36.12	100.64[1]
12	Chesaw.....	Six miles south.....	Finely crystalline, light gray.....	3.56	2.04	52.56	trace	93.75	trace	40.88	99.04[1]
13	Chesaw.....	Buckhorn Mountain	Light gray.....	0.86	0.72	54.10	0.35	96.61	0.73	42.50	98.53[1]
14	Chesaw.....	Buckhorn Mountain	Dark gray.....	4.54	0.61	50.69	1.21	90.51	2.54	42.85	99.90[1]

15	Chesaw	Southwest	Dark gray	2.36	0.88	51.89	0.96	92.66	2.02	43.21	99.30[1]
16	Chesaw	Southwest	Light gray	6.58	0.26	49.90	1.26	89.17	2.64	41.50	99.50[1]
17	Riverside	West one and one-half miles	Brownish blue	2.24	4.00	49.05	2.28	.....	.....	41.32	98.89[1]
18	Riverside	Scotch Creek basin	Black to blue	12.00	1.80	45.91	4.20	.....	.....	36.44	100.35[1]
19	Riverside	Scotch Creek basin	Crystalline, white	1.76	1.36	52.42	1.94	.....	.....	41.86	99.34[1]
20	Riverside	West three miles, Johnson Creek	Yellowish white	2.16	21.92	30.22	1.02	.....	.....	44.62	99.94[1]
21	Riverside	West three miles	Black	10.44	2.66	1.78	47.53	.....	.....	37.02	99.43[1]
22	Riverside	Sec. 25, T. 35 N., R. 25 E.	White	5.02	3.13	32.07	14.93	.....	.....	43.06	98.21[1]
23	Riverside	West	Yellow	12.86	1.32	31.25	10.60	.....	.....	43.20	99.23[1]
			PEND OREILLE COUNTY.								
24	Cement	Jordan property	Yellowish to light gray, crystalline	6.92	2.92	48.65	1.24	86.59	2.60	39.43	99.07[1]
25	Cement	Jordan property	Weathered same as No. 24	3.10	1.68	51.12	0.96	90.99	2.01	41.90	98.76[1]
26	Cement	Jordan property	Dark blue, compact, brittle	17.04	10.08	40.47	3.91	.....	.....	29.02	100.52[1]
27	Cement	Jordan property	Dark blue, compact, brittle	3.60	4.12	49.28	trace	.....	.....	41.94	98.94[1]
28	Cement	Jordan property	.....	11.40	1.06	48.75	none	.....	.....	.....	.....[2]
29	Cement	Jordan property	.....	8.00	1.10	49.71	trace	.....	.....	.....	.....[2]
30	Cement	Jordan property	.....	15.60	2.30	45.60	trace	.....	.....	.....	.....[2]
31	Cement	Jordan property	.....	10.60	2.10	47.62	trace	.....	.....	.....	.....[2]
32	Cement	Jordan property	.....	11.30	1.70	45.97	trace	.....	.....	.....	.....[2]
33	Cement	Jordan property	.....	11.40	1.80	40.30	trace	.....	.....	.....	.....[2]
34	Cement	Jordan property	.....	8.80	2.00	47.77	trace	.....	.....	.....	.....[2]
35	Cement	Jordan property	.....	26.04	14.54	29.34	3.32	.....	.....	.....	.....[2]
36	Cement	Jordan property	.....	16.60	2.92	38.28	4.40	.....	.....	.....	.....[2]
37	Cement	Jordan property	.....	19.40	7.60	34.40	trace	.....	.....	.....	.....[2]
38	Cement	Jordan property	.....	5.00	3.80	31.05	16.54	.....	.....	.....	.....[2]
39	Cement	Jordan property	.....	trace	2.50	30.25	17.12	.....	.....	.....	.....[2]
40	Cement	Jordan property	.....	5.00	4.90	30.97	15.67	.....	.....	.....	.....[2]
41	Cement	Jordan property	.....	4.60	1.30	30.52	18.10	.....	.....	.....	.....[2]
			STEVENS COUNTY.								
42	Kettle Falls	Fishe's ranch, one mile south of river	Light gray, gneissoid	0.38	0.28	54.06	2.03	96.53	4.26	43.15	99.86[1]
43	Kettle Falls	Fishe's ranch, at flume	Same as No. 42, more solid	1.56	0.64	54.62	1.12	97.22	2.35	42.34	99.73[1]
44	Kettle Falls	Peaceful Valley	Gray, crystalline, stratified	1.70	0.56	54.57	0.56	96.13	1.17	42.18	99.01[1]
45	Bossburg	Northeast one and one-half miles, on road	Gray, coarsely crystalline	4.68	1.56	51.05	trace	91.86	trace	42.53	99.82[1]
46	Bossburg	Silver Queen Mountain	White or gray, finely crystalline	0.86	0.26	54.86	0.96	97.65	2.01	42.50	99.34[1]
47	Bossburg	Silver Queen Mountain	White or gray, finely crystalline	0.51	0.34	54.26	1.15	96.48	2.41	42.30	98.56[1]
48	Bossburg	Silver Queen Mountain	White or gray, finely crystalline	0.65	0.19	54.32	0.96	96.69	2.01	42.54	98.66[1]
49	Bossburg	Silver Queen Mountain	White or gray, finely crystalline	0.78	0.51	53.90	1.08	95.94	2.26	42.00	98.27[1]
50	Ryan	One-half mile east	Cream white, gneissoid, brown streak	1.00	trace	53.96	1.60	96.01	3.36	43.27	99.83[1]
51	Northport	South two miles, in old quarry	White to cream, finely crystalline	1.98	0.40	52.25	2.92	93.90	6.13	42.87	100.42[1]
52	Valley	Jump Off Joe Lake	Dark blue, compact	1.58	1.78	54.02	1.23	96.46	2.58	41.38	100.02[1]
53	Colville	South two miles	Dark gray to black, crystalline	2.20	1.60	53.06	1.78	94.44	3.72	42.76	99.62[1]
54	Colville	South two miles	Dark gray to black, crystalline	2.00	1.08	53.55	0.76	95.31	1.59	42.64	100.04[1]

No.	Nearest Town.	LOCATION.	CHARACTER OF MATERIALS.	SiO_2	R_2O_3	CaO	MgO	$CaCO_3$	$MgCO_3$	Loss	Total
55	Colville	Jefferson Quarry	Light gray, white brown stripe	3.49	0.24	51.54	1.11	91.74	2.33	42.62	100.00[1]
56	Addy	Little Lake, near Crystal quarry	Dolomitic, brownish	1.12	0.96	29.56	23.62	52.51	59.60	43.61	98.87[1]
57	Colville	Mud Lake, Weisner's farm	Dolomitic marl, snow white	2.18	0.80	4.99	36.13	8.83	75.87	54.09	98.37[1]
58	Evans	Idaho Brick and Lime Company	Light gray, compact	1.15	trace	54.21	trace	96.64	trace	43.64	98.32[1]
59	Northport	Deep Creek	Crystalline, white	1.76	trace	55.37	trace	98.85	.....	42.50	99.63[1]
60	Northport	South three miles	Fine grained, light gray	6.41	2.09	51.51	trace	91.96	trace	40.13	100.14[1]
61	Addy	Sec. 3, T. 33 N., R. 39 E.	White or light gray, coarse	2.84	1.31	31.25	19.12	.....	.....	43.89	98.41[1]
62	Valley	Jump Off Joe Lake	Dark blue, compact	1.47	0.65	54.12	none	96.64	none	43.50	99.74[1]
63	Valley	Secs. 30 and 31, T. 31 N., R. 39 E.	Light gray	6.48	4.20	2.52	41.53	.....	.....	43.60	98.33[1]
64	Valley	Secs. 1, 6, 7 and 12, T. 31 N., R. 40 E.	Pinkish in color	18.18	2.06	24.74	16.10	.....	.....	38.92	100.00[3]
65	Valley	Secs. 8 and 9, T. 31 N., R. 39 E.	Coarsely crystalline, dark color	5.79	1.28	1.69	42.07	.....	.....	49.17	100.00[3]
66	Valley	Sec. 19, T. 31 N., R. 39 E. and Secs. 24 and 25, T. 31 N., R. 38 E.	Coarsely crystalline, pink color	0.89	0.58	none	45.76	.....	.....	52.77	100.00[3]
67	Chewelah	Sec. 32, T. 32 N., R. 41 E.	Dark colored	3.15	0.41	31.55	20.11	.....	.....	43.91	99.13[1]
68	Chewelah	Sec. 5, T. 32 N., R. 41 E.	White	5.26	1.46	32.56	14.90	.....	.....	43.96	98.14[1]
69	Colville	South two miles	Sample 20 feet below surface	3.16	0.92	51.22	2.15	.....	.....	41.95	99.40[1]
70	Colville	South two miles	Sample 35 feet below surface	14.84	3.40	44.88	1.20	.....	.....	34.90	99.22[1]
71	Colville	South two miles	Sample 60 feet below surface	1.96	2.68	48.73	3.26	.....	.....	42.00	98.63[1]
72	Colville	South two miles	Sample 80 feet below surface	5.44	1.36	47.87	3.96	.....	.....	40.37	99.00[1]
73	Colville	Old Dominion	Coarsely crystalline, white	3.98	0.41	33.07	21.15	.....	.....	41.19	99.80[1]
74	Colville	Sec. 13, T. 35 N., R. 39 E.	Crystalline, dark gray	0.82	0.63	32.77	19.02	.....	.....	46.73	99.97[3]
75	Colville	Sec. 13, T. 35 N., R. 39 E.	Crystalline, dark gray	3.91	1.23	30.99	20.28	.....	.....	43.72	100.13[1]
76	Colville	Mill Creek	White	2.61	.....	53.68	0.76	95.85	.....	42.89	99.94[3]
77	Colville	Mill Creek	Dark gray	3.12	0.93	52.04	0.67	99.98	.....	43.22	99.98[3]
78	Colville	Clugston Creek	Jefferson quarry, white	0.87	.....	55.16	0.21	98.50	.....	43.77	100.01[3]
79	Colville	Clugston Creek	Jefferson quarry, pink	3.49	0.24	51.54	1.11	91.96	.....	42.46	100.00[3]
80	Colville	Clugston Creek	Keystone quarry, white	0.98	trace	53.96	1.25	94.57	.....	43.76	99.95[3]
81	Colville	Clugston Creek	Keystone quarry, gray	0.82	trace	54.81	0.70	97.87	.....	43.56	99.89[3]
82	Colville	Clugston Creek	Keystone quarry, dark gray	1.89	trace	42.60	10.05	76.07	.....	44.63	100.17[3]
83	Addy	Stranger Creek	Crystal quarry, white	0.91	.....	31.80	20.68	.....	.....	46.64	100.03[3]
84	Addy	Stranger Creek	Crystal quarry, dark gray	0.98	.....	30.08	22.21	.....	.....	46.70	99.97[3]
85	Addy	Stranger Creek	Light colored	0.56	0.40	55.15	0.79	.....	.....	43.12	100.02[3]
86	Evans	Idaho Brick and Lime Company	Fine grained, gray	0.96	0.20	55.10	0.36	98.39	.....	43.28	99.90[3]
87	Bossburg	North two miles	Fine grained, white	2.49	0.98	31.56	18.56	56.35	.....	45.91	99.95[3]
88	Bossburg	North two miles	Coarse grained, gray	0.13	.....	54.95	0.54	98.12	.....	44.22	99.84[3]
89	Bossburg	North two miles	Medium grained, white	0.98	0.36	54.48	0.79	97.28	.....	43.26	99.87[1]
90	Bossburg	East of Columbia	Coarsely crystalline, gray	0.65	0.31	54.64	0.81	97.57	.....	42.92	99.33[1]
91	Bossburg	East of Columbia	Coarsely crystalline, gray	0.51	0.45	54.85	trace	97.94	.....	43.10	98.91[1]
92	Bossburg	East of Columbia	Coarsely crystalline, gray	1.13	0.26	53.65	1.46	95.80	.....	42.68	99.18[1]
93	Bossburg	East of Columbia	Coarsely crystalline, gray	0.96	0.20	54.16	1.06	97.71	.....	43.00	99.38[1]
94	Bossburg	East of Columbia	Coarsely crystalline, gray	1.41	0.41	53.16	0.96	94.94	.....	43.16	99.10[1]
95	Ryan	.....	Fine grained	1.00	.....	53.96	1.60	96.36	.....	43.27	99.83[3]

SAN JUAN COUNTY.

96	Roche Harbor.	.....	.....	0.44	1.13	.....	.....	98.21	.....	.....	99.78
97	Roche Harbor.	.....	.....	0.27	0.21	.....	.....	99.06	0.46	.....	100.00
98	Roche Harbor.	.....	.....	0.20	0.30	.....	.....	98.57	1.02	.....	100.09
99	East Sound....	Sec. 31, T. 37 N., R. 3 W.....	.....	1.14	trace	54.44	0.31	97.21	.....	43.11	99.00[1]
100	East Sound....	Sec. 25, T. 37 N., R. 2 W.....	.....	1.64	0.06	54.43	0.39	97.21	.....	43.30	99.82[1]
101	East Sound....	Sec. 19, T. 37 N., R. 1 W.....	.....	4.28	0.96	52.36	0.64	93.50	.....	42.00	100.24[1]
102	East Sound....	.....	.....	1.61	0.04	.....	.....	97.45	.....	.....	.....
103	East Sound....	.....	.....	1.14	.....	.....	.....	97.23	0.31	.....	.....

SKAGIT COUNTY.

104	Concrete.....	Northeast one mile.....	Coarse grained, light colored.....	5.36	1.12	52.08	1.08	93.00	.....	.....	.....[4]
105	Concrete.....	Northeast one mile.....	Coarse grained, light colored.....	4.26	1.22	52.70	0.91	94.10	.....	.....	.....[4]
106	Concrete.....	Northeast one mile.....	Coarse grained, light colored.....	5.56	0.98	51.98	1.10	92.82	.....	.....	.....[4]
107	Concrete.....	Northeast one mile.....	Coarse grained, light colored.....	2.06	1.12	54.25	trace	96.69	.....	.....	.....[4]
108	Concrete.....	Northeast one mile.....	Coarse grained, light colored.....	4.68	1.20	52.30	0.92	93.39	.....	.....	.....[4]
109	Concrete.....	Northeast one mile.....	Coarse grained, light colored.....	6.76	0.92	51.20	1.16	91.42	.....	.....	.....[4]
110	Concrete.....	Northeast one mile.....	Coarse grained, light colored.....	3.72	1.24	53.22	0.62	95.03	.....	.....	.....[4]
111	Concrete.....	Northeast one mile.....	Coarse grained, light colored.....	8.36	0.96	50.70	1.04	90.53	.....	.....	.....[4]
112	Concrete.....	Northeast one mile.....	Coarse grained, light colored.....	2.92	1.06	53.60	trace	95.71	.....	.....	.....[4]
113	Concrete.....	Northeast one mile.....	Coarse grained, light colored.....	8.40	0.88	50.30	1.22	89.82	.....	.....	.....[4]
114	Concrete.....	Jackman Creek	Crystalline, light colored.....	1.94	0.22	54.92	trace	98.07	.....	42.67	99.75[1]
115	Concrete.....	Jackman Creek	Crystalline, light colored.....	3.36	1.78	51.85	0.30	92.59	.....	42.61	99.90[1]
116	Sauk.....	Secs. 9, 15 and 16, T. 35 N., R. 9 E.....	Crystalline, light colored.....	1.36	0.82	54.77	trace	97.80	.....	42.05	99.00[1]
117	Rockport.....	North one mile.....	Finely crystalline, light gray.....	0.78	0.72	54.95	trace	98.12	.....	43.50	99.95[1]

SNOHOMISH COUNTY.

118	Granite Falls..	Secs. 7 and 8, T. 30 N., R. 7 E.....	Coarsely crystalline, dark gray.....	0.22	trace	55.12	trace	98.43	.....	43.86	99.20[1]
119	Granite Falls..	Secs. 7 and 8, T. 30 N., R. 7 E.....	Coarsely crystalline, dark gray.....	0.16	0.13	54.44	0.42	97.22	.....	44.00	99.60[1]

WHATCOM COUNTY.

120	Kendall.....	Sec. 23, T. 40 N., R. 5 E.....	Coarse grained, light gray.....	1.44	0.92	54.36	trace	97.07	.....	43.17	99.89[1]
121	Kendall.....	Sec. 22, T. 40 N., R. 5 E.....	Coarse grained, medium gray.....	8.96	2.44	48.46	1.01	86.53	.....	39.16	100.07[1]
122	Kendall.....	Sec. 22, T. 40 N., R. 5 E.....	Average sample.....	3.04	0.76	52.48	0.30	93.71	.....	42.14	98.72[1]
123	Kendall.....	.....	.....	1.52	0.35	.....	.....	97.48	1.26	.....	.....[5]
124	Kendall.....	.....	.....	1.37	0.42	.....	.....	98.72	0.26	.....	.....[5]
125	Maple Falls....	Sec. 22, T. 40 N., R. 6 E.....	Coarsely crystalline, light colored.....	0.48	1.00	52.88	2.05	94.42	.....	43.14	99.45[1]

CLAYS.

ASOTIN COUNTY.

No.	Nearest Town.	LOCATION.	CHARACTER OF MATERIALS.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Loss	Total
1	Asotin.....	Four miles up river.....	Compace, yellowish to gray.....	54.52	12.14	6.20	trace	2.07	1.92	1.30	8.06	99.19[1]

CHELAN COUNTY.

2	Chelan.....	.....	Light gray in color.....	59.84	16.40	4.10	5.84	0.36	1.62	2.84	8.76	99.77[10]

OKANOGAN COUNTY.

3	Havilla.....	One mile east.....	Plastic, yellowish white.....	57.68	15.74	8.14	5.77	3.75	1.32	1.41	6.17	99.98[1]
4	Van Slyke P.O.	One mile north.....	Bluish, gritty, plastic.....	65.66	16.66	6.56	3.10	3.76	undt.		1.40	97.14[1]
5	Riverside.....	Scotch Creek basin, Hess farm.....	Blue, plastic, some grit.....	59.48	18.24	6.92	2.95	3.62	1.95	2.21	5.26	99.15[1]
6	Riverside.....	Scotch Creek basin.....	Blue, plastic, some grit.....	58.48	17.29	6.76	5.25	2.95	1.10	1.98	4.26	98.69[1]
7	Conconully....	Pendergass farm	Earthy, plastic, gritty.....	58.76	19.42	8.82	6.48	1.34	1.01	0.66	3.10	99.59[1]

PEND OREILLE COUNTY.

8	Metaline.....	Two miles above on county road.....	Fine, siliceous, dusty.....	54.88	20.08	7.57	3.98	3.08	undt.		7.61	97.21 [1]
9	Metaline Falls.	Inland Cement Co. hill.....	Blue, plastic, fine.....	63.40	16.10	4.01	5.34	2.75	undt.		5.00	96.69 [1]
10	Cement.....	Jordan property	Earthy, yellowish, finely stratified.....	63.28	18.64	7.52	1.97	3.16	1.70	0.70	2.26	99.60 [1]
11	Cement.....	Jordan property	Massive, yellowish brown.....	62.96	18.82	7.35	2.00	3.62	undt.		3.00	97.75 [1]
12	Cement.....	.....	.....	61.58	20.29	5.95	1.34	2.30	.....	2.10	6.08	99.55[10]
13	Cement.....	.....	Blue clay.....	57.53	28.37		1.88	4.50	.....	.....	.....	.....[11]
14	Cement.....	Jordan property	Buff clay.....	68.33	22.71		1.88	2.55	.....	.....	.....	.....[11]
15	Cement.....	Jordan property	Buff clay.....	66.32	24.48		1.96	2.68	.....	.....	.....	.....[11]
16	Cement.....	Jordan property	Buff colored.....	71.74	20.56		1.97	2.23	.....	.....	.....	.....[11]
17	Cement.....	Jordan property	Buff colored.....	68.94	21.64		1.36	2.24	.....	.....	.....	.....[11]
18	Cement.....	Jordan property	Buff colored.....	76.00	17.02		1.46	1.66	.....	.....	.....	.....[11]
19	Cement.....	Jordan property	Blue colored.....	76.52	16.38		1.36	1.77	.....	.....	.....	.....[11]
20	Cement.....	Jordan property	Buff in color.....	70.90	20.04		1.30	1.99	.....	.....	.....	.....[11]
21	Cement.....	Jordan property	Buff colored.....	77.95	15.53		1.61	1.26	.....	.....	.....	.....[11]
22	Cement.....	Jordan property	Buff colored.....	71.58	17.93		1.46	1.67	.....	.....	.....	.....[11]
23	Cement.....	Jordan property	Blue in color.....	54.10	32.38		7.03	0.86	.....	.....	.....	.....[12]
24	Cement.....	Jordan property	Buff colored.....	60.80	26.20		9.74	3.15	.....	.....	.....	.....[12]
25	Cement.....	Jordan property	Buff colored.....	65.60	27.12		6.16	.....	.....	.....	.....	..... [6]
26	Cement.....	Jordan property	Blue	63.00	24.40		2.85	trace	.....	.....	.....	..... [6]

27	Cement.....	Jordan property	Blue colored.....	61.10		24.60	1.99	.....	.....	.....	.....	.....	[6]
28	Cement.....	Jordan property	Buff	62.30		29.25	1.79	none	.....	.....	.....	.....	[6]
29	Cement.....	Jordan property	Buff in color.....	60.80		26.50	1.37	none	.....	.....	.....	.....	[6]
30	Cement.....	Jordan property	Buff in color.....	63.50		20.80	5.66	trace	.....	.....	.....	.....	[6]
31	Cement.....	Jordan property	Buff in color.....	59.10		24.50	2.53	.....	.....	.....	.....	.....	[6]
32	Metaline Falls.	Inland Portland Cement Co.....	Grayish colored.....	63.20		20.20	5.34	2.75	.....	.....	.....	.....	[7]
33	Metaline Falls.	Inland Portland Cement Co.....	Blue in color.....	57.02		20.62	7.01	3.67	.....	.....	.....	.....	[7]

STEVENS COUNTY.

34	Kettle Falls....	In city, river grade.....	Very fine, gray, stratified.....	56.98	17.74	7.22	4.08	5.31	0.86	1.31	6.07	99.41	[1]
35	Northport.....	South two miles, Trumbull's farm.....	Gray, massive, fine silt.....	59.76	17.29	5.71	2.94	4.11	1.80	1.51	6.86	100.04	[1]
36	Northport.....	Northeast two miles, railway cut.....	Earthy, gray, compact, stratified.....	57.16	16.10	8.26	4.15	4.06	1.46	1.13	7.13	99.51	[1]
37	Valley.....	Iron mines	White, very fine grained, plastic.....	69.12	23.40	0.96	trace	0.96	0.17	0.15	4.92	99.64	[1]
38	Northport.....	Across river, railway cut.....	Yellowish gray, compact.....	56.72	15.69	9.34	4.43	3.13	1.19	1.09	6.64	98.23	[1]
39	Marcus.....	Across river, railway cut.....	Dark gray, compact.....	50.68	19.79	9.45	6.48	3.15	2.31		undt.	98.72	[1]
40	Bossburg.....	On Rasmussen's place.....	Finely stratified, gray.....	55.90	20.69	7.55	3.63	2.32	undt.		6.40	96.49	[1]
41	Evans.....	North one-half mile.....	Finely stratified, gray.....	56.48	20.52	7.16	4.18	3.49	undt.		5.10	98.93	[1]
42	Evans.....	North one-half mile.....	Finely stratified, gray.....	57.68	22.60	8.26	5.95	2.08	undt.		1.69	98.26	[1]
43	Bossburg.....	In town	Gray in color.....	60.14	20.00	5.68	4.07	2.85	undt.		4.50	97.24	[1]

SAN JUAN COUNTY.

44	Roche Harbor.	San Juan Islands.....	.....	55.81		26.28	4.34	3.39	3.98		6.11	99.91	[6]
45	Roche Harbor.	San Juan Islands.....	.....	56.35		24.62	3.66	2.58	3.94		7.52	98.98	[6]
46	East Sound....	Orcas Island	Fine grained, light gray.....	59.92	21.08	4.56	3.88	2.90	1.16	0.97	4.74	99.21	[1]
47	East Sound....	Orcas Island	.....	57.30		21.40	5.10	3.10	2.10		.....	.....	
48	East Sound....	Orcas Island	.....	53.20		23.90	6.30	4.10	2.90		.....	.....	
50	Lopez.....	Lopez Island	Fine grained, light gray.....	59.40	19.58	6.44	4.26	4.13	0.75	0.41	4.38	99.35	[1]

SKAGIT COUNTY.

51	Concrete.....	Baker River	Stratified, light gray.....	57.06	16.16	8.30	5.96	3.20	2.22		6.22	.....	[9]
52	Concrete.....	Baker River	Stratified, light gray.....	57.24		24.76	5.44	4.86	.....	.....	.....	.....	[9]
53	Concrete.....	Baker River	Stratified, light gray.....	57.42		24.68	5.66	4.58	.....	.....	.....	.....	[9]
54	Concrete.....	Baker River	Stratified, light gray.....	56.78		25.56	5.12	4.30	.....	.....	.....	.....	[9]
55	Concrete.....	Baker River	Stratified, light gray.....	57.36		25.06	5.36	4.56	.....	.....	.....	.....	[9]
56	Concrete.....	Baker River	Stratified, light gray.....	56.64		25.80	5.26	4.26	.....	.....	.....	.....	[9]
57	Concrete.....	Jackman Creek	Very fine grained, light gray.....	60.21	16.21	5.10	2.90	4.15	2.10	1.51	7.10	99.26	[1]
58	Concrete.....	Jackman Creek	Very fine grained, light gray.....	54.18	18.05	9.91	4.17	4.51	1.17	1.04	6.98	100.01	[1]
59	Sauk.....	North one mile.....	Very fine grained, light gray.....	56.18	17.37	8.89	4.14	4.60	1.76	1.43	5.03	99.40	[1]

SNOHOMISH COUNTY.

No.	Nearest Town.	LOCATION.	CHARACTER OF MATERIALS.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Loss	Total
60	Index.....	Up river two miles.....	Fine grained, gray.....	53.56	25.26	8.86	2.66	2.05	0.43	0.27	6.02	99.11[1]

WHATCOM COUNTY.

61	Kendall.....	Sec. 9, T. 40 N., R. 5 E.....	Fine grained, gray to yellow.....	59.92	17.85	7.31	6.08	3.15	.....	.....	5.42	99.73[1]
62	Kendall.....	Sec. 34, T. 40 N., R. 5 E.....	Fine grained, dark gray.....	54.16	14.97	7.91	2.62	13.46	.....	.....	.....	.....[1]
63	Kendall.....	.....	.....	61.27	25.30		2.96	4.68	.....	.....	.....	.....[5]
64	Kendall.....	.....	.....	57.06	26.80		10.62	1.13	2.56		.....	.....[13]

SHALES.

ASOTIN COUNTY.

No.	Nearest Town.	LOCATION.	CHARACTER OF MATERIALS.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Loss	Total
1	Anatone.....	Lime hill	Decomposed yellow, fine slabs.....	26.28	16.89	1.57	28.72	trace	undt.	undt.	27.17	100.63[1]
2	Anatone.....	Lime hill	Near basaltic contact on west.....	9.82	2.24		48.33	0.78	undt.	undt.	38.18	99.36[1]
3	Anatone.....	Lime hill	Red and green near bluff on north.....	72.56	12.04	1.38	3.16	2.10	undt.	undt.	6.15	97.39[1]

PEND OREILLE COUNTY.

4	Metaline.....	Three miles above on road.....	Dark and carbonaceous.....	14.76	2.80		42.63	2.26	undt.		35.84	98.23[1]
5	Metaline Falls.	South bank, Sullivan Creek.....	Gray, stratified, limey.....	44.16	19.06	6.09	13.06	2.15	undt.		14.36	99.45[1]
6	Metaline Falls.	North bank, Sullivan Creek.....	Gray, stratified, limey.....	48.22	17.46	4.38	12.10	2.24	undt.		11.29	98.73[1]
7	Cement.....	Jordan property	Brownish, stratified	54.68	22.15	9.09	2.08	2.52	1.75	1.42	4.78	98.42[1]
8	Metaline Falls.	Sullivan Creek	.....	41.61	22.84		15.07	2.83	.....	.....	.....	.....[7]
9	Metaline Falls.	Sullivan Creek	.....	23.54	15.20		30.22	2.38	.....	.....	.....	.....[7]
10	Metaline Falls.	Sullivan Creek	.....	10.54	6.42		43.01	2.99	.....	.....	.....	.....[7]
11	Metaline Falls.	Sullivan Creek	.....	48.26	21.84		12.10	2.24	.....	.....	.....	.....[7]
									$CaCO_3$	$MgCO_3$		
12	Metaline Falls.	Sand Creek	.....	72.04	13.72		.....	.....	4.07	4.13	.....	.....[7]
13	Metaline Falls.	Sand Creek	.....	70.84	14.40		.....	.....	5.00	4.13	.....	.....[7]
14	Metaline Falls.	Sand Creek	.....	69.40	14.20		.....	.....	6.26	4.34	.....	.....[7]
15	Metaline Falls.	Sand Creek	.....	66.04	14.12		.....	.....	6.57	6.95	.....	.....[7]
16	Metaline Falls.	Sand Creek	.....	64.60	14.88		.....	.....	5.27	7.64	.....	.....[7]

17	Metaline Falls.	Sand Creek		65.64	11.20			9.70	9.44			[7]
18	Metaline Falls.	Sand Creek		65.96	12.64			9.92	8.75			[7]
19	Metaline Falls.	Sand Creek		67.08	10.84			9.55	8.60			[7]
20	Metaline Falls.	Sand Creek		65.72	8.84			12.99	10.15			[7]
21	Metaline Falls.	Sand Creek		66.48	12.08			11.42	8.40			[7]
22	Metaline Falls.	Sand Creek		70.68	12.80			6.10	7.12			[7]
23	Metaline Falls.	Sand Creek		71.12	13.36			5.32	5.30			[7]
24	Metaline Falls.	Sand Creek		71.40	14.04			5.48	6.91			[7]
25	Metaline Falls.	Sand Creek		68.04	12.04			9.55	6.39			[7]
26	Metaline Falls.	Sand Creek		74.40	13.00			2.81	6.78			[7]

STEVENS COUNTY.

								K_2O	Na_2O		
27	Kettle Falls....	Five miles south, Heidiger road.....	Finely stratified, brownish.....	72.01	12.52	4.35	2.02	1.99	1.80	1.36	3.18	99.23[1]
28	Kettle Falls....	Six miles south, Heidiger road, near spring	Brown, hard, stratified, brittle.....	58.15	16.90	9.22	2.57	3.02	1.36	1.71	4.12	99.63[1]
29	Valley.....	Near iron mine, four miles northeast....	White to purple, flaky.....	28.36	2.29	5.39	18.56	6.01	undt.	undt.	32.41	98.41[1]
30	Colville.....	Seven miles northeast on Clugsten Creek.	Almost black, hard, compact.....	72.64	12.70	3.00	1.64	1.97	1.30	1.43	3.54	99.78[1]
31	Colville.....	Three miles south on road; east of road.	Soft, light gray, slate-like.....	41.28	10.31	2.33	21.93	3.12	undt.	undt.	19.42	98.39[1]
32	Addy.....	On road to Crystal quarry.....	Decomposed, brownish, soft.....	59.24	7.36	3.00	11.08	2.80	undt.	undt.	6.40	99.88[1]
33	Bossburg.....	Two miles east, near road.....	Blue-gray, silicious	66.68	10.82	5.02	4.62	1.31	undt.	undt.	7.22	95.67[1]
34	Bossburg.....	Bonanza mine, four miles east.....	Bluish, soft, chalk-like.....	57.56	22.48	10.40	0.45	3.14	undt.	undt.	2.78	96.81[1]
35	Addy.....	Secs. 19 and 30, T. 34 N., R. 39 E.....	Fine grained, light gray.....	54.41	16.83	3.21	12.54	trace	undt.	undt.	12.83	99.82[1]
36	Northport.....	S. E. three and one-half miles, near road	Bluish gray	82.64	7.52	5.26	0.99	0.96	undt.	undt.	2.23	99.60[1]

SAN JUAN COUNTY.

37	Orcas Island...			62.80	19.20	10.20	0.90	undt.	undt.		
38	Orcas Island...			39.80	21.62	29.10	2.91	2.15			

WHATCOM COUNTY.

39	Kendall.....			66.01	17.65	8.01	3.15				[13]
40	Kendall.....			72.69	22.19	2.16	2.47				[13]

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APPENDIX B.

United States Government Specifications for Portland Cement, and Interpretation of Results.

The following with reference to the specifications for Portland cement and interpretation of results is taken from Mineral Resources, U. S. Geological Survey, 1911, Part II, pp. 501-505:

SPECIFICATIONS.

Since June, 1911, a committee composed of Government engineers in conference with representative consumers and manufacturers and special committees of the national engineering societies, has been engaged in formulating a single specification for Portland cement to be used by all departments of the government. This committee has had in view the desirability of an agreement between the specifications in use by the public and those adopted by the government. At a departmental conference held February 13, 1912, a set of liberal specifications was unanimously adopted, and simultaneously with their publication the following executive order was issued:

EXECUTIVE ORDER.

It is hereby ordered that all Portland cement that may hereafter be purchased by any department, bureau, office, or independent establishment of the government, or that may be used in construction work connected with any of the aforesaid branches of the government service, shall conform in every respect to the specification for Portland cement adopted by the departmental conference at the meeting held at the Bureau of Standards on February 13, 1912, and approved by the heads of the several departments (to be known as the United States government specification for Portland cement): Provided, however, that such specification may be modified from time to time by any similar departmental conference, with the approval of the heads of the several departments. Wm. H. Taft.

The White House, April 30, 1912.

UNITED STATES GOVERNMENT SPECIFICATION FOR PORTLAND CEMENT.*

Specification.

Definition.—1. The cement shall be the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate mixture of properly proportioned argillaceous and calcareous substances, with only such additions susbequent to calcining as may be necessary to control certain properties. Such additions shall not exceed 3 per cent, by weight, of the calcined product.

Composition.—2. In the finished cement the following limits shall not be exceeded:

	Per cent.
Loss on ignition for 15 minutes	4
Insoluble residue	1
Sulphuric anhydride (SO_3)	1.75
Magnesia (MgO)	4

Specific gravity.—3. The specific gravity of the cement shall not be less than 3.10. Should the cement as received fall below this requirement, a second test may be made upon a sample heated for 30 minutes at a very dull red heat.

Fineness.—4. Ninety-two per cent. of the cement, by weight, shall pass through the No. 100 sieve, and 75 per cent. shall pass through the No. 200 sieve.

Soundness.—5. Pats of neat cement prepared and treated as hereinafter prescribed shall remain firm and hard and show no sign of distortion, checking, cracking, or disintegrating. If the cement fails to meet the prescribed steaming test, the cement may be rejected or the steaming test repeated after seven or more days, at the option of the engineer.

Time of setting.—6. The cement shall not acquire its initial set in less than 45 minutes and must have acquired its final set within ten hours.

* United States government specification for Portland Cement: Cir. Bur. Standards No. 33, U. S. Dept. Com. and Labor, May 1, 1912.

Tensile strength.—7. Briquets made of neat cement, after being kept in moist air for 24 hours and the rest of the time in water, shall develop tensile stength per square inch as follows:

	Pounds.
After 7 days	500
After 28 days	600

8. Briquets made up of 1 part cement and 3 parts standard Ottawa sand, by weight, shall develop tensile stength per square inch as follows:

	Pounds.
After 7 days	200
After 28 days	275

9. The average of the tensile strengths developed at each age by the briquets in any set made from one sample is to be considered the strength of the sample at that age, excluding any results that are manifestly faulty.

10. The average strength of the sand-mortar briquets at 28 days shall show an increase over the average strength at 7 days.

Brand.—11. Bids for furnishing cement or for doing work in which cement is to be used shall state the brand of cement proposed to be furnished and the mill at which made. The right is reserved to reject any cement which has not established itself as a high-grade Portland cement and has not been made by the same mill for two years and given satisfaction in use for at least one year under climatic and other conditions at least equal in severity to those of the work proposed.

Packages.—12. The cement shall be delivered in sacks, barrels, or other suitable packages (to be specified by the engineer), and shall be dry and free from lumps. Each package shall be plainly labeled with the name of the brand and of the manufacturer.

13. A sack of cement shall contain 94 pounds net. A barrel shall contain 376 pounds net. Any package that is short weight or broken or that contains damaged cement may be rejected, or accepted as a fractional package, at the option of the engineer.

Inspection.—14. The cement shall be tested in accordance with the standard methods hereinafter prescribed. In general

the cement will be inspected and tested after delivery, but partial or complete inspection at the mill may be called for in the specifications or contract. Tests may be made to determine the chemical composition, specific gravity, fineness, soundness, time of setting, and tensile strength, and a cement may be rejected in case it fails to meet any of the specified requirements. An agent of the contractor may be present at the making of the tests or they may be repeated in his presence.

15. In case of failure of any of the tests, and if the contractor so desires, the engineer may, if he deem it to the interest of the United States, have any or all of the tests made or repeated by the Bureau of Standards, United States department of commerce and labor, in the manner hereinafter specified, all expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer.

After these articles of specification the subject is continued in detail in the Bureau of Standards circular under the heads, "Standard methods of testing," "Methods of chemical analysis," "Interpretation of results," and "Auxiliary specifications," the last being mainly Bureau of Standards specifications for certain apparatus to be used in making tests. Under "Interpretation of results" a number of points are discussed that are of great importance in connection with the specifications quoted above.

INTERPRETATION OF RESULTS.*

Chemical.

The composition of normal Portland cement has been the subject of a great deal of investigation, and it can be said that the quantities of silica, alumina, oxide of iron, lime, magnesia, and sulphuric anhydride can vary within fairly wide limits without materially affecting the quality of the material.

A normal American Portland cement which meets the standard specifications for soundness, setting time, and tensile

*Circ. Bur. Standards No. 33, U. S. Dept. Commerce and Labor, May 1, 1912.

strength has an approximate composition within the following limits:

	Per cent.
Silica (SiO_2)	19—25
Alumina (Al_2O_3)	5—9
Iron oxide (Fe_2O_3)	2—4
Lime (CaO)	60—64
Magnesia (MgO)	1—4
Sulphur trioxide (SO_3)	1—1.75
Loss on ignition	0.5—3.00
Insoluble residue	0.1—1.00

It is also true that a number of cements have been made both here and abroad which have passed all standard physical tests in which these limits have been exceeded in one or more particulars, and it is equally true that a sound and satisfactory cement does not necessarily result from the above composition.

It is probable that further investigation will give a clearer understanding of the constitution of Portland cement, but at present chemical analysis furnishes but little indication of the quality of the material.

Defective cement usually results from imperfect manufacture, not from faulty composition. Cement made from very finely ground material, thoroughly mixed and properly burned, may be perfectly sound when containing more than the usual quantity of lime, while a cement low in lime may be entirely unsound due to careless manufacture.

The analysis of a cement will show the uniformity in composition of the product from individual mills, but will furnish little or no indication of the quality of the material. Occasional analysis should, however, be made for record and to determine the quantity of sulphuric anhydride and magnesia present.

The ground clinker as it comes from the mill is usually quick setting which requires correction. This is usually accomplished by the addition of a small quantity of more or less hydrated calcium sulphate either gypsum or plaster of Paris. Experience and practice have shown that an addition of 3 per cent or less is sufficient for the purpose.

Three per cent of calcium sulphate ($CaSO_4$) contains about 1.75 per cent. sulphuric anhydride (SO_3), and as this has been considered the maximum quantity necessary to control time of set, the specification limits the SO_3 content to 1.75 per cent.

The specification prohibits the addition of any material subsequent to calcination except the 3 per cent of calcium sulphate permitted to regulate time of set. Other additions may be difficult or impossible to detect even by a careful mill inspection during the process of manufacture, but as the normal adulterant would be ground raw material, an excess of "insoluble residue" would reveal the addition of siliceous material, and an excess in "loss on ignition" would point to the addition of calcareous material when either is added in sufficient quantity to make the adulteration profitable.

The effect of relatively small quantities of magnesia (MgO) in normal Portland cement, while still under investigation, can be considered harmless. Earlier investigators believed that as magnesia had a slower rate of hydration than lime, the hydration of any free magnesia (MgO) present would occur after the cement had set and cause disintegration.

The effect of magnesia was considered especially injurious when the cement was exposed to the action of sea water. More recent investigation has shown that cement can be made which is perfectly sound under all conditions when containing 5 per cent of magnesia and it has also been found that the lime in Portland cement exposed to sea water is replaced by magnesia.

The maximum limit for magnesia has been set at 4 per cent, and it has been established that this quantity is not injurious and it is high enought to permit the use of large quantities of raw material available in most sections of the country.

Physical.

Specific gravity.—The specific gravity is obtained from the formula:

$$\text{Specific gravity} = \frac{\text{Weight of cement in grams.}}{\text{Displaced volume in cubic centimeters.}}$$

The specific gravity of a Portland cement is not an indication of its cementing value. It will vary with the constituents of the cement, especially with the content of iron oxide. Thus the white or very light Portland cements, containing only a fraction of a per cent of iron oxide, usually have a comparatively

low specific gravity ranging from 3.05 to 3.15, while a cement containing 3 to 4 per cent or more of iron oxide may have a specific gravity of 3.20 or even higher. It is materially affected by the temperature and duration of burning the cement, the hard-burned cement having the higher specific gravity. A comparatively low specific gravity does not necessarily indicate that a cement is underburned or adulterated, as large percentages of raw materials could be added to a cement with a normally high specific gravity before the gravity would be reduced below 3.10.

If a Portland cement fresh from the mill normally has a comparatively low specific gravity, upon aging it may absorb sufficient moisture and carbon dioxide to reduce the gravity below 3.10. It has been found that this does not appreciably affect the cementing value of the material; in fact, many cements are unsound until they have been aged. Thus a redetermination is permitted upon a sample heated to a temperature sufficient to drive off any moisture which might be absorbed by the cement subsequent to manufacturing, but would not drive off any carbon dioxide nor correct underburning in the process of manufacturing the cement.

The value of the specific gravity determination lies in the fact that it is easily made in the field or laboratory, and when the normal specific gravity of the cement is known, any considerable variation in quality due to underburning or the addition of foreign materials may be detected.

Fineness.—Only the extremely fine powder of cement called flour possesses appreciable cementing qualities and the coarser particles are practically inert. No sieve is fine enough to determine the flour in cement, nor is there any other means of accurately and practically measuring the flour. Some cements grind easier than others; thus, although a larger percentage of one cement may pass the 200-mesh sieve than another, the former may have a smaller percentage of actual flour due to the difference in the hardness and the character of the clinker and the method used in grinding. Thus the cementing value of different cements can not be compared directly upon their apparent fineness through a 200-mesh sieve. With cement from the same

mill, with similar clinker and grinding machinery, however, it is probable that the greater percentage which passes the 200-mesh sieve the greater the percentage of flour in that particular cement.

Normal consistency.—The quantity of water used in making the paste from which the pats for soundness, tests of setting, and the briquets are made is very important and may vitally affect the results obtained. The determination consists in measuring the quantity of water required to bring a cement to a certain state of plasticity.

In determining the normal consistency by the ball method, after mixing the paste it should be formed into a ball with as little working as possible and a new batch of cement should be mixed for each trial paste. In order to obtain just the requisite quantity of paste to form a ball 2 inches in diameter, a measure made from a pipe with a 2-inch inside diameter cut 1 1-3 inches long would be found convenient. The section of pipe should be open at both ends, so that it can be pushed down into the paste on the mixing table and the excess paste cut off with a trowel. The appearance of the ball, using the correct quantity of water, is [illustrated in the Bureau of Standards circular].

Mixing.—The homogeneity of the cement paste is dependent upon the thoroughness of the mixing, and this may have considerable inffuence upon the time of setting and the strength of the briquets.

Soundness.—The purpose of this test is to detect those qualities in a cement which tend to destroy the strength and durability. Unsoundness is usually manifested by a change in volume, which causes cracking, swelling, or disintegration. If the pat is not properly made, or if it is placed where it will be subject to any drying during the first 24 hours, it may develop what are known as shrinkage cracks, which are not an indication of unsoundness and should not be confused with disintegration cracks. * * * No shrinkage cracks should develop after the first 24 or 28 hours. The failure of the pats to remain on the glass nor the cracking of the glass to which the pat is at-

tached does not necessarily indicate unsoundness. In molding the pats the cement paste should first be flattened on the glass and the pat formed by drawing the trowel from the outer edge toward the center. * * *

Time of setting.—The purpose of this test is to determine the time which elapses from the moment water is added until the paste ceases to be plastic and the time required for it to obtain a certain degree of hardness. The determination of the "initial set," or when plasticity ceases, is the more important, as a distrubance of the material after this time may cause a loss of strength, and thus it is important that the mixing and molding or the incorporating of the material into the work be accomplished within this time. The time of setting is usually determined upon one of the pats which is to be used for the soundness test, the top surface being flattened somewhat. * * * In using the Gillmore needles care should be taken to apply the needles in a vertical position and perpendicular to the surface of the pat. An arrangement [has been perfected] for mounting the Gillmore needles so that they are always perpendicular to the surface of the pat. The rate of setting and hardening may be materially affected by slight changes in temperature. The percentage of water used in gaging and the humidity of the moist closet in which the test pieces are stored may also affect the setting somewhat.

Tensile tests.—Consistent results can only be obtained by exercising great care in molding and testing the briquets. The correct method of filling the mold [is illustrated in the circular]. In testing, the sides of the briquet and the clips should be thoroughly cleaned and free from grains of sand or dirt, which would prevent a good bearing, and the briquet should be carefully centered in the clips so as to avoid cross strains. It may be considered good laboratory practice if the individual briquets of any set do not show a greater variation from the mean value than 8 per cent for sand mixtures and 12 per cent for neat mixtures.

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