# PORTLAND, NATURAL, AND PUZZOLAN CEMENTS.

## PORTLAND CEMENT MATERIALS NEAR DUBUQUE, IOWA.

By Ernest F. Burchard.

### INTRODUCTION.

In the summer of 1905 a detailed geologic survey of the Lancaster quadrangle, lying mainly in Wisconsin and Iowa, was made by J. R. Banister, A. W. Lewis, and the writer. During the survey particular attention was given to the investigation of certain natural resources of the district, among them the beds of limestone and clay, with a view to ascertaining their value for making Portland cement. The Iowa Geological Survey cooperated in the work to the extent of making chemical analyses of some of the materials collected. This analytical work, carried on under the supervision of S. W. Beyer at the Iowa College of Agriculture and Mechanic Arts, at Ames, is still unfinished. It is planned further to ascertain the proportions in which the materials must be combined in order to produce the best cement, to burn the material on a small scale, and to make tests for fineness and tensile strength of the resulting cement as soon as the necessary machinery is installed in the college laboratories. In case these results are as favorable as there is reason to believe they will prove to be, the information should be of considerable importance, for the district appears to be so situated as to need a cement plant.

The trade territory would be confined to the region west, north, and northeast of Dubuque, and would comprise a large part of the States of Iowa, Minnesota, and Wisconsin. A plant near Dubuque would at present have to meet competition from Mason City, Iowa; Hannibal, Mo.; and Dixon, Ill. Dubuque has the advantage of cheap water transportation, besides four direct rail lines to the north, and might fairly be able to control the trade along the river up to and including St. Paul and Minneapolis.

## MAPS AND OTHER PUBLICATIONS.

Dubuque, Iowa, is on the south edge of the Lancaster quadrangle, which extends northward about 35 miles from latitude 42° 30′. East and west of Dubuque the quadrangle extends, respectively, 9 and 17 miles. The United States Geological Survey has issued topographic and geologic maps of this quadrangle which are together available in the geologic folio of the Lancaster-Mineral Point area (folio No. 145, Geologic Atlas U. S., price 25 cents). The topographic maps are also issued separately and sold for 5 cents each. Other useful maps and discussions of the geology of the district have been issued by the State surveys, as follows:

Calvin, Samuel, and Bain, H. F. Geology of Dubuque County: Iowa Geol. Survey, vol. 10, 1900, pp. 379–622.

Beyer, S. W. Supplementary report on Portland cement materials in Iowa: Bull. Iowa Geol. Survey No. 3, 1906, 36 pp.

Grant, U. S. Report on the lead and zinc deposits of southwestern Wisconsin, with atlas: Bull. Wisconsin Geol. and Nat. Hist. Survey No. 14, 1906, 100 pp.

## AGE AND DISTRIBUTION OF THE ROCKS.

The principal rocks exposed along Mississippi River and near the mouths of its tributaries between Dubuque, Iowa, and Cassville, Wis., together with their ages and essential features, are comprised in the following table:

*Rocks exposed north of Dubuque, Iowa.*

| System. | Formation. | Character. | Thickness. |
|---|---|---|---|
| | | | *Feet.* |
| Quaternary | | Loess | 1-60 |
| | | Residual clay | 1-15 |
| Ordovician | Galena | Dolomite and chert | 235 |
| | Platteville | Limestone and shale | 55 |
| | St. Peter | Sandstone | 70 |
| | Prairie du Chien | Cherty magnesian limestone | 1-40 exposed. |

A few miles back from the river the Maquoketa shale and Niagara limestone are present in the section, above the Galena, but these rocks have no bearing on the present subject. The beds of particular importance are the limestone and shale of the Platteville, the basal Galena beds, and the residual clay and loess, all of which are exposed in the bluffs of the Mississippi River gorge between Dubuque and Cassville.

## MANUFACTURING SITES.

Along the greater part of the river front between these cities the bluffs rise steeply to a height of 60 to 100 feet above the flood plain and then slope more gently to a total height of 150 to 200 feet above the river. On both sides of the river a railroad runs close to the base of the bluff. In several lateral ravines and valleys large enough for mill sites the Platteville beds are favorably situated for quarrying, so that the broken rock may be loaded into a mill by gravity. Five such localities were sectioned and sampled in detail. In the order of their distances from Dubuque they are as follows: (1) Near Zollicoffer Lake, Peru Township, Iowa, in the SW. ¼ sec. 23, T. 90 N., R. 2 E.; (2) at Spechts Ferry, Iowa; (3) near Potosi Station, Wis., in the SE. ¼ sec. 4, T. 2 N., R. 3 W.; (4) about 1 mile above Waupeton, Iowa, in the NE. ¼ sec. 25, T. 91 N., R. 1 W.; (5) near McCartney, Wis., in sec. 4, T. 2 N., R. 4 W.

## CHARACTER OF MATERIALS.

A generalized section of the Platteville includes the following divisions:

*Generalized section of Platteville formation.*

| | Feet. |
|---|---|
| 4. Limestone, principally in thin beds, and shale | 10–15 |
| 3. Limestone, fine grained, brittle, and thin bedded | 15–25 |
| 2. Limestone, magnesian, thick bedded | 15–25 |
| 1. Shale, bluish, sandy in places | 1– 5 |
| | 41–70 |

Nos. 3 and 4 of the above generalized section contain the purest limestone, but in places part of No. 2 also is found to contain less than 5 per cent of magnesium carbonate. The following table gives the stratigraphic details and the corresponding chemical analyses of the beds at two localities in Iowa:

*Analyses of Platteville limestone and shale.*

[Analyst, L. G. Michael, Iowa College of Agriculture and Mechanic Arts, Ames, Iowa.]

| No. | Location and character of bed. | Thickness. | | Constituents. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $SiO_2$. | $Fe_2O_3+Al_2O_3$. | $CaCO_3$. | $MgCO_3$. | Alkalies, as $K_2O$ | $SO_3$. | Combined $H_2O$. | $H_2O$ (moisture). |
| | *Near Zollicoffer Lake, Peru Township, Iowa, sec. 23, T. 90 N., R. 2 E.* | | | | | | | | | | |
| | Limestone, becoming magnesian above. | *Ft.* | *in.* | | | | | | | | |
| 7 | Limestone, subcrystalline, medium beds | 2 | 6 | 8.28 | 4.67 | 80.14 | 2.37 | ........ | 2.60 | 2.17 | 0.13 |
| 6 | Limestone, thin beds | 5 | | 3.26 | .83 | 90.20 | 2.65 | ........ | 1.64 | 1.84 | .06 |
| 5 | Limestone, thin beds | 5 | 10 | 4.54 | 2.54 | 86.33 | 3.54 | ........ | .22 | 2.62 | .08 |
| 4 | Limestone, in heavy bed | 1 | 4 | 3.85 | 6.03 | 84.16 | 1.93 | ........ | .64 | 4.23 | .03 |
| 3a | Limestone, thin bands interbedded with shale (No. 3) | 2 | 3 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 3 | Shale, exclusive of limestone bands (No. 3a) | 5 | 10 | 50.22 | 9.08+12.45 | 13.83 | 2.96 | 5.23 | 1.16 | 3.81 | 1.71 |
| 2 | Limestone, coarse grained | 6 | | 6.79 | 4.61 | 78.24 | 5.12 | ........ | 1.74 | 3.28 | .04 |
| 1 | Limestone, fine grained, thin beds, unexposed below | 12 | | 8.02 | 5.78 | 77.93 | 4.43 | ........ | .22 | 3.18 | .16 |
| | *Spechts Ferry, Iowa, sec. 3, T. 90 N., R. 2 E.* | | | | | | | | | | |
| | Limestone, becoming magnesian above | 10 | | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 5 | Limestone | 10 | | 5.74 | 6.69 | 83.56 | .25 | ........ | 1.77 | 1.50 | .10 |
| 4a | Limestone, thin bands interbedded with shale (No. 4) | 2 | 8 | 11.24 | 6.31 | 78.51 | .24 | ........ | 1.58 | 1.85 | .10 |
| 4 | Shale, exclusive of limestone bands (No. 4a) | 6 | 9 | 49.32 | 8.30+20.16 | 9.52 | 3.21 | 4.68 | Tr. | 4.82 | .72 |
| 3 | Limestone, massive beds | 20 | | 10.71 | 6.69 | 78.67 | .28 | ........ | 1.51 | 1.70 | .15 |
| 2 | Limestone, medium beds | 5 | | 7.94 | 12.05 | 73.38 | 3.52 | ........ | 1.69 | 1.40 | .10 |
| 1 | Limestone, thin beds | 9 | | 7.50 | 6.17 | 79.50 | 3.97 | ........ | 1.48 | 1.60 | .15 |
| | Limestone, heavy magnesian beds | 7 | 6 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| | Sandstone. | | | | | | | | | | |

Sections made at the other three places are as follows:

*Section of Platteville-Galena beds near Potosi Station, Wis.*

| | Ft. | in. |
|---|---|---|
| 6. Limestone, fine grained, thin bedded (Galena) | 12 | 0 |
| 5. Shale, including 2 feet 4 inches of interbedded limestone, total | 7 | 10 |
| 4. Limestone, fine grained, thin bedded | 3 | 6 |
| 3. Limestone, even grained, medium bedded | 3 | 0 |
| 2. Limestone, crystalline, thin bedded | 12 | 0 |
| 1. Limestone, fine grained, thin, wavy bedded (partly concealed) | 18 | 0 |

*Section of Platteville-Galena beds near Waupeton, Iowa.*

| | Ft. | in. |
|---|---|---|
| 5. Limestone, subcrystalline, with carbonaceous shale partings (Galena) | 12 | 0 |
| 4. Shale | 0 | 4 |
| 3. Limestone, similar to No. 5 | 1 | 5 |
| 2. Shale, blue, including 7 inches of thin limestone partings, total | 6 | 3 |
| 1. Limestone, heavy bedded | 5 | 0 |

*Section of Platteville-Galena beds near McCartney, Wis.*

| | Ft. | in. |
|---|---|---|
| 6. Limestone, subcrystalline, with carbonaceous shale partings (Galena) | 12 | 0 |
| 5. Shale, calcareous, including 6 inches of thin limestone partings, total | 3 | 6 |
| 4. Shale, blue | 2 | 0 |
| Concealed | 5 | 0 |
| 3. Limestone, bluish, crystalline, thin bedded | 5 | 0 |
| Concealed | 10 | 0 |
| 2. Limestone, fine grained, thin bedded | 7 | 0 |
| Concealed | 13 | 0 |
| 1. Limestone, heavy bedded, buff to blue, probably magnesian | 6 | 0 |

The shale beds, exclusive of the limestone bands, comprising No. 5 of the section at Potosi Station, No. 2, at Waupeton, and Nos. 4 and 5, at McCartney, were analyzed with results given below:

*Analyses of shale from upper division of Platteville formation.*

[Analyst, L. G. Michael, Ames, Iowa.]

| | Potosi. | Waupeton. | McCartney. |
|---|---|---|---|
| Silica ($SiO_2$) | 48.88 | 50.69 | 49.10 |
| Alumina ($Al_2O_3$) | 14.54 | 15.63 | 17.15 |
| Ferric oxide ($Fe_2O_3$) | 12.00 | 4.83 | 8.46 |
| Calcium carbonate ($CaCO_3$) | 8.58 | 11.15 | 11.04 |
| Magnesium carbonate ($MgCO_3$) | 3.15 | 8.43 | 2.85 |
| Sulphur trioxide ($SO_3$) | 1.26 | 2.65 | 1.69 |
| Alkalies, as $K_2O$ | 6.43 | 1.46 | 3.62 |
| Combined water | 4.48 | 4.64 | 5.36 |
| Moisture | 1.30 | .49 | .91 |

For cement manufacture all these shales should preferably carry higher percentages of silica and less iron oxide in order that the ratio

$Al_2O_3+Fe_2O_3=\frac{SiO_2}{3}$ should be more nearly approximated. The alumina and iron oxide together should not be greater than $\frac{SiO_2}{2}$, and it is apparent from the above analyses that at Potosi Station, as well as at Spechts Ferry, their sum is greater than this. It is desirable, therefore, both on account of the chemical composition and the relative thinness of the shale beds, that some other supply of silica and alumina should be at hand. It is possible that such a supply might be obtained from the residual clay and loess at the top of the hills wherever these materials average rich in silica and poor in lime. An idea of the composition of the clay and loess present in the region can be had from the accompanying analyses. While the samples of clay and loess were not taken from the same sections as the limestone and shale, there is an abundance of this unconsolidated material above the Galena beds at each locality, and its composition is probably such that it may be considered an important factor in the situation.

*Analyses of residual clay and loess from the Driftless Area.* [a]

[Analyst, R. B. Riggs.]

| | 1. | 2. | 3. | 4. | 5. | 6. |
|---|---|---|---|---|---|---|
| $SiO_2$ | 71.13 | 49.59 | 53.09 | 49.13 | 72.68 | 64.61 |
| $Al_2O_3$ | 12.50 | 18.64 | 21.43 | 20.08 | 12.03 | 10.64 |
| $Fe_2O_3$ | 5.52 | 17.19 | 8.53 | 11.04 | 3.53 | 2.61 |
| FeO | .45 | .27 | .86 | .93 | .96 | .51 |
| $TiO_2$ | .45 | .28 | .16 | .13 | .72 | .40 |
| $P_2O_5$ | .02 | .03 | .03 | .04 | .23 | .06 |
| MnO | .04 | .01 | .03 | .06 | .06 | .05 |
| CaO | .85 | .93 | .95 | 1.22 | 1.59 | 5.41 |
| MgO | .38 | .73 | 1.43 | 1.92 | 1.11 | 3.69 |
| $Na_2O$ | 2.19 | .80 | 1.45 | 1.33 | 1.68 | 1.35 |
| $K_2O$ | 1.61 | .93 | .83 | 1.60 | 2.13 | 2.06 |
| $H_2O$ (+H of organic matter) | 4.63 | 10.46 | 10.79 | 11.72 | 2.50 | 2.05 |
| $CO_2$ | .43 | .30 | .29 | .39 | .39 | 6.31 |
| C | .19 | .34 | .22 | 1.09 | .09 | .13 |
| $SO_3$ | | | | | .51 | .11 |

[a] Sixth Ann. Rept. U. S. Geol. Survey, 1885, pp. 250, 282.

Nos. 1 and 2 are samples of clay from the same vertical section, No. 1 having been taken 4½ feet from the surface and No. 2 a little more than 8½ feet from the surface, in contact with the underlying limestone. Nos. 3 and 4 are samples of clay that are similarly related, having been taken, respectively, 3 and 4½ feet from the surface, the latter clay in contact with the rock. No. 5 is loess from Dubuque, Iowa; No. 6 is loess from Galena, Ill.

A review of the character of the materials available shows that a cement manufactured in this district would be of the type made from a mixture of ordinary hard limestone and clay or shale. About 36 per cent of the Portland cement now made in the United States is of this type. Magnesium carbonate, the most objectionable of impurities in raw limestone materials, falls in these rocks well within the maximum allowable limits of 5 to 6 per cent. Certain of the limestone beds that are high in silica resemble very closely in composition the "cement rock" of the well-known Lehigh Portland cement district.

The materials in this district would require very little preliminary drying. The limestone is fairly uniform in texture, but it would need very thorough grinding. The shale, clay, and loess are less refractory, and although the clay and loess carry a few chert or quartz pebbles such objectionable material is not excessive and could be removed by screening.

The Dubuque district is, of course, not ideally situated with regard to a fuel supply, but its distance from the Iowa coal field is not so great as the distance of certain successfully operated cement plants from their fuel base. A possible substitute, at least in part, for coal might be furnished by the great quantities of sawdust and slabs wasted by the several sash and door factories and other lumber mills at Dubuque. This fuel might be utilized in the kilns in the form of producer gas.

# PORTLAND CEMENT MATERIALS IN EASTERN WYOMING.

By Sydney H. Ball.

## INTRODUCTION.

In 1906 the writer examined shale and limestone beds in the vicinity of Newcastle and Cheyenne, Wyo., in order to ascertain the possibility of establishing a Portland cement plant in eastern Wyoming. At present there is no Portland cement plant in Wyoming (see fig. 8), the cement used in the State being shipped either from the Middle West or from Colorado, Utah, or South Dakota. The demand for Portland cement in the Western States is growing enormously. The Government is using large amounts of cement on its reclamation projects in Wyoming and adjoining States, and the mines in Montana and in the Black Hills of South Dakota use large quantities in installing their plants. Further, the railroads must soon use cement or masonry for culverts and bridges or cease to use as fuel western coal of poorer grades, which being light blows out of the smokestacks and starts fires that burn wooden bridges. The consumption of Portland cement in the towns in Wyoming is increasing at a rapid rate and with the introduction of cheaper cement the demand would increase. The conditions would seem to justify the establishment of a Portland cement plant within the State.

In connection with the preparation of this paper, Mr. E. C. Eckel, of the United States Geological Survey, has given the writer the benefit of his experience, and Prof. J. A. Holmes has furnished analyses made in the structural materials laboratory of the United States Geological Survey at St. Louis, Mo., the analysts being A. J. Phillips and P. H. Bates.

## NEWCASTLE.

### SITUATION.

Newcastle is situated in Weston County, Wyo., near the South Dakota line, on the southwestern slope of the Black Hills. It is on the main line of the Burlington and Missouri Valley Railroad, a spur of which runs from the town to large coal mines at Cambria. The country naturally tributary to a Portland cement plant at Newcastle includes northwestern Wyoming, the Black Hills in South Dakota, northwestern Nebraska, and all of Montana. (See fig. 8, p. 240.)

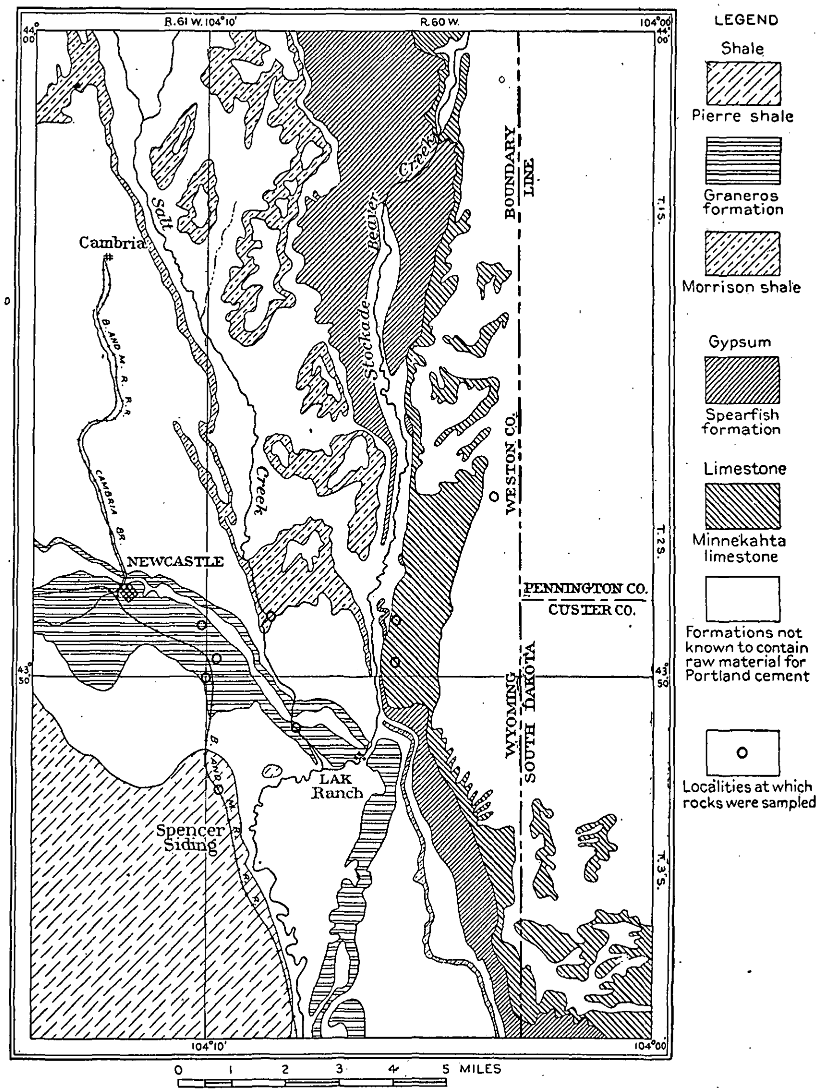


FIG. 7.—Map showing distribution of Portland cement raw materials in vicinity of Newcastle, Wyo. Generalized from geologic map in Newcastle folio, by N. H. Darton.

## TOPOGRAPHY AND GEOLOGY.

North and east of Newcastle, toward the Black Hills, lies a highly dissected plain that rises toward the north, the geology of which has been described by N. H. Darton in the Newcastle folio.[a] Within

[a] Geologic Atlas U. S., folio 107, U. S. Geol. Survey.

the Newcastle quadrangle there are a large number of sedimentary formations, which range in age from Mississippian (Carboniferous) to Recent. These formations (see fig. 7) are distributed in bands which to the north and east of Newcastle have a north-south trend, and in the immediate vicinity of the town and in an area northwest of it occur in layers that course from northwest to southeast. As one travels west and southwest, away from the Black Hills central core of older rocks, he passes successively over younger and younger formations. The older ormations therefore lie northeast and east of Newcastle.

## RAW MATERIALS.

The raw materials used in the manufacture of Portland cement are limestone (which typically contains but little magnesium carbonate) and shale or clay. In the vicinity of Newcastle the Minnekahta limestone, the Morrison shale, the Graneros shale, and the Pierre shale furnish suitable raw materials.

### NATURAL CEMENT ROCK.

A calcareous shale, rather fissile and of light-gray color, a part of the Graneros shale, is exposed on the north side of the small stream that is crossed by the railroad $2\frac{1}{4}$ miles southeast of Newcastle. A thickness of 40 feet of shale is exposed on a small whitish hill west of the railroad. The amount of gypsum in this shale is too small to interfere with its use as a Portland cement material. Interbedded with the shale, 20 feet from the top of the sampled portion, are thin beds of limestone one-half inch thick. The shale occurs here in considerable bodies, which could probably be worked with a steam shovel. The following is an analysis of this limy shale, or shaly limestone, as it appears to be, made by Messrs. Phillips and Bates:

*Analysis of shale from point $2\frac{1}{4}$ miles southeast of Newcastle.*

| | | |
|---|---|---|
| Silica ($SiO_2$) | | 18.10 |
| Alumina ($Al_2O_3$) | | 6.26 |
| Ferric oxide ($Fe_2O_3$) | | .80 |
| Manganese oxide (MnO) | | .50 |
| Lime (CaO) | | 37.57 |
| Magnesia (MgO) | | .76 |
| Sulphuric anhydride ($SO_3$) | | .27 |
| Alkalies | $Na_2O$ | 2.14 |
| | $K_2O$ | .92 |
| Water at 100° C | | 1.25 |
| Ignition loss | | 31.58 |
| | | 100.15 |

This highly clayey limestone would make an excellent base for the manufacture of cement, and if mixed with a small amount of pure limestone (about 10 per cent) would make Portland cement of high grade.

#### LIMESTONE.

*Minnekahta limestone.*—The Minnekahta limestone is exposed on the east side of Stockade Beaver Creek, where it forms the slopes and top of the lower of two benches. Here it is a rather thin-bedded limestone of light-gray or purplish color, averaging less than 40 feet in thickness. It includes at some places a few nodules of flint, but these can be easily separated from the pure limestone in the manufacture of Portland cement, and where the rock was sampled they seem to be absent. The localities at which samples were taken are respectively 1½ and 2¾ miles north and a little east of the L A K ranch, on the east side of Stockade Beaver Creek and the road. Analysis 1, below, is by Mr. P. H. Bates; analysis 2 is by Mr. A. J. Phillips.

*Analyses of Minnekahta limestone.*

| Constituent. | 1. | 2. |
|---|---|---|
| Silica ($SiO_2$) | 1.08 | 1.42 |
| Alumina ($Al_2O_3$) | .33 | .68 |
| Ferric oxide ($Fe_2O_3$) | .77 | .40 |
| Manganese oxide (MnO) | .46 | .11 |
| Lime (CaO) | 53.40 | 52.85 |
| Magnesia (MgO) | .57 | .72 |
| Sulphuric anhydride ($SO_3$) | .12 | .12 |
| Alkalies { $Na_2O$ | .36 | .76 |
| Alkalies { $K_2O$ | .16 | .30 |
| Water at 100° C | .20 | .10 |
| Ignition loss | 42.92 | 42.78 |
| | 100.37 | 100.24 |

This is a pure limestone and an excellent constituent of a Portland cement mixture, containing low magnesium carbonate and sulphur. The supply of limestone here is practically inexhaustible, and since the bed dips gently to the west, the rock could be readily quarried and shot down to or nearly to the railroad by gravity. A branch railroad could be built from the main line to either point cheaply.

*Pahasapa limestone.*—The Pahasapa limestone is exposed in a thin band about 1½ miles west of Stockade Beaver Creek. An analysis of the rock by Mr. P. H. Bates is as follows:

*Analysis of Pahasapa limestone.*

| | |
|---|---|
| Silica ($SiO_2$) | 4.02 |
| Alumina ($Al_2O_3$) | .10 |
| Ferric oxide ($Fe_2O_3$) | .94 |
| Manganese oxide (MnO) | .22 |
| Lime (CaO) | 36.68 |
| Magnesia (MgO) | 14.14 |

| | | |
|---|---|---|
| Sulphuric anhydride ($SO_3$) | | 0.05 |
| Alkalies | $Na_2O$ | .33 |
| | $K_2O$ | .09 |
| Water at 100° C | | .25 |
| Ignition loss | | 43.65 |
| | | 100.47 |

This rock contains too much magnesia to be used for the manufacture of Portland cement.

### SHALE.

*Morrison shale.*—The most important exposures of Morrison shale, which is the lowest Cretaceous formation here and is 150 feet thick, cover considerable portions of the drainage basin of Salt Creek. The shale at the supposed coal prospect on the east bank of Salt Creek 3 miles above its mouth is carbonaceous and slightly plastic. It contains a little iron pyrite in nodules and few if any sand grains. An average sample from the 20-foot face exposed here was analyzed by Mr. P. H. Bates.

*Analysis of Morrison shale.*

| | | |
|---|---|---|
| Silica ($SiO_2$) | | 45.78 |
| Alumina ($Al_2O_3$) | | 12.92 |
| Ferric oxide ($Fe_2O_3$) | | 3.96 |
| Manganese oxide (MnO) | | .33 |
| Lime (CaO) | | .56 |
| Magnesia (MgO) | | .73 |
| Sulphuric anhydride ($SO_3$) | | .42 |
| Alkalies | $Na_2O$ | .64 |
| | $K_2O$ | .50 |
| Water at 100° C | | 8.26 |
| Ignition loss | | 26.32 |
| | | 100.42 |

This is a high-grade normal shale, in which the ratio of silica to combined alumina and ferric iron is practically 3 to 1—an ideal ratio. The magnesia and alkalies are very low, and although silica is low the loss by ignition (largely carbonaceous matter) is very high. This carbonaceous matter can be considered as so much fuel added to the mixture, and its presence will considerably decrease the cost of burning.

*Graneros shale.*—The Graneros shale underlies the broad valley south of Newcastle, comprising an area extending from the L A K ranch northwestward to and for several miles along the Burlington and Missouri River Railroad. From the ranch the outcrop of the formation swings approximately southward, and because of steeper dips becomes narrower. It consists mainly of dark-gray shale, and in the vicinity of Newcastle is about 1,100 feet thick. Thin veinlets of gypsum are common in the shale, but at no point are these so abundant as to make it unfit for use as Portland cement material.

Of three samples analyzed, one (analysis 1 below) was collected immediately south of the point where the road from Newcastle to the L A K ranch crosses Salt Creek. The shale here is dark gray and fissile. No gypsum was seen at this point, although some fragments of shale are covered with a yellowish coating which has an astringent taste, probably due to the presence of ferrous sulphate. The second sample (analysis 2) was collected at a point 2¼ miles southeast of Newcastle, between the wagon road and the railroad. Here the shale is black and fissile and dips gently to the southwest. The hill from which the sample was taken is 40 feet high, and the surrounding valley is underlain by shale, presumably of similar composition. The shale contains numerous crystals of gypsum, and gypsum occurs also in thin plates along the joint faces. It is soft and could doubtless be worked by a steam shovel with but little blasting. The third sample was collected from a hill 1½ miles south of east of Newcastle, near a prominent ridge formed by the sandstone lens in the Graneros shale. At this place there is a large body of gray shale without sand grains or gypsum, but its analysis is much less satisfactory than those of the two previous samples. Analysis 1, below, is by A. J. Phillips and P. H. Bates; analyses 2 and 3 are by P. H. Bates.

*Analyses of samples of Graneros shale.*

| Constituent. | 1. | 2. | 3. |
|---|---|---|---|
| Silica ($SiO_2$) | 67.55 | 58.82 | 68.30 |
| Alumina ($Al_2O_3$) | 17.58 | 16.43 | 14.65 |
| Ferric oxide ($Fe_2O_3$) | .47 | 4.47 | .37 |
| Manganese oxide (MnO) | .18 | .24 | .33 |
| Lime (CaO) | .36 | .54 | 1.18 |
| Magnesia (MgO) | .74 | 1.68 | 1.03 |
| Sulphuric anhydride ($SO_3$) | .50 | 1.32 | .09 |
| Alkalies $Na_2O$ | .21 | .33 | .30 |
| Alkalies $K_2O$ | .79 | 2.18 | .39 |
| Water at 100° C. | ........ | 6.39 | 6.82 |
| Ignition loss | 11.68 | 7.93 | 6.56 |
| | 100.26 | 100.33 | 100.02 |

Analyses 1 and 2 show a normal shale with a high content of silica and a ratio of silica to iron and alumina that would make the rock a satisfactory cement-making material. Analysis 1, however, shows a percentage of ferric oxide so small that the cement mixture would be infusible, but analysis 2 is in every way that of a shale well fitted for making Portland cement. Analysis 3 shows that the rock analyzed contains entirely too much silica and too little ferric iron to be of value.

*Pierre shale.*—Pierre shale covers a large area lying south and southwest of Newcastle, the nearest exposures being situated 3 miles from town. The Pierre is a dark-gray shale, about 1,250 feet thick. It is characterized in places by limestone concretions, some of which are very large. A sample was taken along the railroad track 1 mile above Spencer siding, where the shale is greenish gray in color, fine grained, and without gypsum. It is soft and could be readily mined by steam shovel. The following analysis is by Phillips and Bates:

*Analysis of Pierre shale.*

| | |
|---|---|
| Silica ($SiO_2$) | 60.66 |
| Alumina ($Al_2O_3$) | 22.13 |
| Ferric oxide ($Fe_2O_3$) | 1.21 |
| Manganese oxide (MnO) | .44 |
| Lime (CaO) | 1.59 |
| Magnesia (MgO) | 1.54 |
| Sulphuric anhydride ($SO_3$) | .43 |
| Alkalies $Na_2O$ | .53 |
| Alkalies $K_2O$ | 2.16 |
| Ignition loss | 9.28 |
| | 99.97 |

The shale has high silica and rather low magnesia and alkalies. Its silica content is 2.6 times that of the alumina and ferric iron, the iron content being so small that the rock would form with limestone an infusible mixture.

## GYPSUM.

Two or three per cent of gypsum is usually added to the clinker of Portland cement to retard setting. Gypsum occurs in considerable amount in the "Red Beds" (Spearfish formation) exposed along Stockade Beaver Creek.

## ECONOMIC CONDITIONS.

Some of the rocks just described are excellent raw material for Portland cement, and the supply at the points where the samples were taken is adequate to run a Portland cement plant for a long time. Further, if the present outcrop of any of these limestones or shales were exhausted, the same rock could be found beneath a thin covering of soil over large areas in the immediate vicinity. The average sample collected represents thicknesses of 20 to 150 feet. The analyses represent not alone the shale or limestone at the point where samples were taken, but give a fair idea of the shale or limestone along the same strike for a long distance.

The best combination for a Portland cement mixture is about 90 per cent of the natural cement rock and 10 per cent of the Minnekahta limestone. The highly clayey limestone or natural cement rock occurs along the railroad, and the limestone could be obtained by running a spur to a point on Stockade Beaver Creek 1 mile above the L A K ranch. This branch road, which would not be more than

5 miles long, would have a gentle grade. Coal could be shipped from Cambria at a maximum cost of $1 per ton f. o. b. at the plant. This coal[a] furnishes a fair amount of heat, and although high in sulphur and ash, the former would largely disappear in the burning and the latter would be incorporated with the cement. The Portland cement plant should be situated on the railroad at the outcrop of the natural cement rock. A well sunk here for the water necessary to run the plant would probably strike flowing water at a depth of 1,000 to 1,500 feet from the surface.

If limestone and shale are to be used, the best combination appears to be the Graneros or the Morrison shale and the Minnekahta limestone. The most desirable Graneros shale is that sampled from the hill approximately 2¼ miles southeast of Newcastle, between the railroad and the wagon road, and the plant should be situated on the railroad at this point. A branch railroad, approximately 5 miles long, following the depression marked by the exposure of the Graneros shale and swinging slightly to the north of the L A K ranch and thence to Stockade Beaver Creek, would reach ledges of Minnekahta limestone. The use of the Morrison shale would require a railroad with two spurs, one up Stockade Beaver Creek for limestone and the other up Salt Creek for shale. In this instance the mill would most advantageously be situated at the fork of the spurs. It is possible, however, that suitable exposures of shale could be found on or immediately west of Stockade Beaver Creek, in which case both limestone and shale would be close to a plant situated on Stockade Beaver Creek and using its water. The mill would then be located 4 or 5 miles above the L A K ranch.

## RÉSUMÉ.

The region tributary to Newcastle is rather large, and although the town has but one main railroad the cement could no doubt be easily marketed. The raw materials are high in grade and abundant in quantity, and cheap fuel of fair quality is at hand. With good management a Portland cement plant situated at Newcastle could unquestionably be run at a profit.

## VICINITY OF CHEYENNE.

Cheyenne, the capital of Wyoming, is in Laramie County, in the southeast corner of the State. It lies on the main lines of the Union Pacific and Chicago, Burlington and Quincy railroads, and from it the Colorado and Southern Railroad runs northward to connect with the Chicago and Northwestern Railroad, and the Union Pacific runs

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[a] Report on operations of coal-testing plant of the United Statse Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904: Prof. Paper U. S. Geol. Survey No. 48, pp. 263, 946, 953, 1313.

southward to Denver. The map (fig. 8) shows that the area to which a Portland cement plant in this portion of Wyoming would ship its product includes eastern Wyoming, western Nebraska, northeastern Colorado, and a part of northwestern Kansas.

### TOPOGRAPHY AND GEOLOGY.

Solid rocks are not exposed in the immediate vicinity of Cheyenne, but along the east edge of the Laramie Front Range there is practically the same succession of Paleozoic and Mesozoic rocks that occurs in the Black Hills. These old rocks are crossed by the Colorado and Southern Railroad at two points, and were examined by the writer at Iron Mountain station, about 40 miles from Cheyenne. At Iron Mountain the rocks are tilted steeply to the east and the mountain front is in

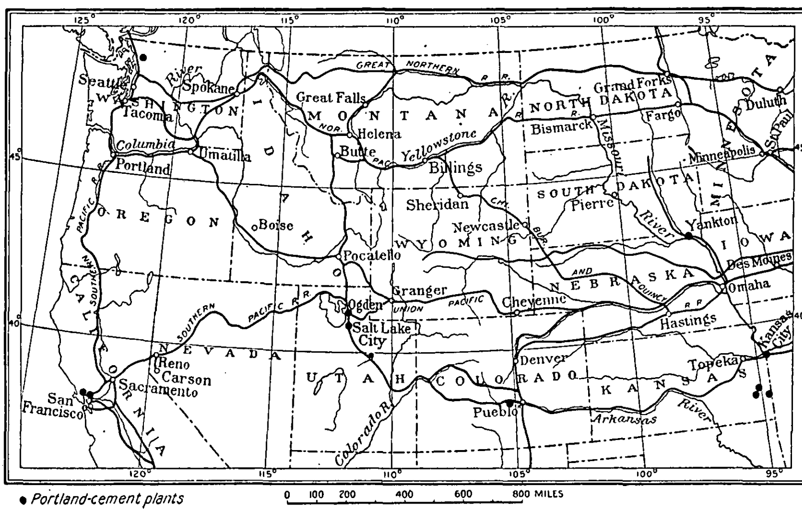


FIG. 8.—Map showing location of Cheyenne and Newcastle, Wyo., in relation to established Portland cement plants and transcontinental railroads.

consequence marked by rugged hogbacks and valleys, formed respectively on resistant sandstone beds and soft shales. The strata in general strike north-south and dip eastward at an angle of about 70.°

### RAW MATERIALS.

The formations sampled in the vicinity of Iron Mountain include limestones from the Niobrara formation and the Minnekahta limestone, and shales from the Graneros formation and the Pierre shale.

#### LIMESTONE.

*Niobrara formation.*—The best limestone sampled is from a hill of Niobrara which lies east of the end of the Bradley spur, across a narrow flat. It is a thin-bedded shaly white limestone and is here and there fossiliferous. The rock shows at many places small yellowishbrown iron stains 1½ inches in diameter. The limestone is practically on edge and could be cheaply quarried, possibly by the use of steam shovels, although considerable blasting would probably be necessary with increase in the depth of the quarry. About 60 feet of this limestone is exposed, but it is probable that a greater thickness could be proved by test pits in the flat to the west. The rock was traced for a distance of one-eighth of a mile on this same hill, and again outcrops across a small brook to the south. The highest point of the exposure is about 100 feet above the valley and unquestionably there is sufficient limestone here to last a large plant many years. The following analysis by Mr. A. J. Phillips is that of a sample taken across 60 feet of the limestone.

*Analysis of Niobrara limestone.*

| | |
|---|---|
| Silica ($SiO_2$) | 6.44 |
| Alumina ($Al_2O_3$) | 1.46 |
| Ferric oxide ($Fe_2O_3$) | 2.32 |
| Manganese oxide (MnO) | .11 |
| Lime (CaO) | 45.90 |
| Magnesia (MgO) | 2.65 |
| Sulphuric anhydride ($SO_3$) | .07 |
| Alkalies ($K_2O$) | .66 |
| Water at 100° C | .55 |
| Water above 100° C | .33 |
| Ignition loss | 39.71 |
| | 100.10 |

This is a good limestone for cement making, although the percentage of silica as compared with that of the combined alumina and ferric oxide is low. Magnesian carbonate is not particularly high, while sulphur, the alkalies, and silica are exceedingly low.

*Minnekahta limestone.*—A little over one-half mile west of Bradley station the Minnekahta limestone (Carboniferous) forms a prominent escarpment and bench extending parallel to the front of the range. It can be readily recognized from its topographic form, and from the fact that it is underlain and overlain by red beds. The limestone is 50 feet thick. In the escarpment it dips S. 80° E. at an angle of 65°, and to the west, on the bench or terrace, it becomes approximately flat. It is gray, purplish, or white in color, and is mostly fine grained, dense, and rather hard. Joints are common throughout the mass and these would be of considerable advantage in quarrying. Its situation for quarrying, however, is unfortunate, since either the overlying red shales, which mask the lower portion of the cliff, would have to be shot off before the limestone could be quarried, or the quarry would have to be located upon the top of the bench and an expensive tramway built to the flat below. A railroad to the base of the cliff would probably have a rather steep grade. A sample taken across 50 feet of this formation was analyzed by A. J. Phillips with the following result:

*Analysis of Minnekahta limestone.*

| | |
|---|---|
| Silica ($SiO_2$) | 10.52 |
| Alumina ($Al_2O_3$) | .46 |
| Ferric oxide ($Fe_2O_3$) | 1.55 |
| Manganese oxide (MnO) | .14 |
| Lime (CaO) | 43.30 |
| Magnesia (MgO) | 3.53 |
| Sulphuric anhydride ($SO_3$) | .06 |
| Alkalies ($Na_2O$) | .05 |
| Alkalies ($K_2O$) | .70 |
| Water at 100° C | .50 |
| Ignition loss | 39.22 |
| | 100.03 |

This limestone, having a high silica content and a comparatively low sum of alumina and ferric oxide, is much poorer in quality than the Niobrara; otherwise it is fairly good, containing low sulphur and not prohibitively high magnesia. Better analyses of particular beds of the Minnekahta limestone have been obtained by private parties.

## SHALE.

*Graneros shale.*—At the end of the railroad spur at Bradley station 140 feet of shale is exposed in a trough lying between the Dakota sandstone hogback on the west and the hogback formed by the sandstone lens in the Graneros formation on the east. The upper 25 feet of the shale, which here dips N. 85° E. at an angle of 80°, is sandy and is unfit for making Portland cement. The lower 115 feet, however, is a dark-gray shale, slightly plastic, with little or no grit. A few ironstone nodules occur in the shale, but these have been included in the sample and are evidently not detrimental. The shale outcrops for three-eighths of a mile south and at least 1½ miles north of Bradley spur. It is soft and could be readily quarried by steam shovel. An analysis by Mr. A. J. Phillips of a sample taken across the middle 40 feet of the shale follows:

*Analysis of Graneros shale.*

| | |
|---|---|
| Silica ($SiO_2$) | 63.60 |
| Alumina ($Al_2O_3$) | 14.66 |
| Ferric oxide ($Fe_2O_3$) | 7.44 |
| Manganese oxide (MnO) | .20 |
| Lime (CaO) | .78 |
| Magnesia (MgO) | .46 |
| Sulphuric anhydride ($SO_3$) | .53 |
| Alkalies ($Na_2O$) | .37 |
| Alkalies ($K_2O$) | 1.79 |
| Water at 100° C | 2.86 |
| Ignition loss | 7.64 |
| | 100.33 |

This is a normal shale with high silica and an ideal ratio between alumina and ferric oxide and silica. The magnesia and the alkalies are rather low, while there is sufficient iron present to insure a fusible cement matrix.

*Pierre shale.*—The Pierre shale was sampled on the west side of the railroad track three-fourths of a mile N. 20° W. of Bradley station. The railroad is one-fourth of a mile due east of the shale deposit, and test pits would doubtless expose similar shale under the terrace gravels on the railroad east of the locality sampled. The shale is dark gray in color and is soft and fissile, many of the beds being paper thin; ellipsoidal masses in it are stained by iron, and it contains a very little selenite (transparent platy gypsum). Without much question it could be worked with a steam shovel. The following analysis, made by Mr. A. J. Phillips, is that of a sample taken across 100 feet of the rock:

*Analysis of Pierre shale.*

| | |
|---|---|
| Silica ($SiO_2$) | 62.34 |
| Alumina ($Al_2O_3$) | 21.98 |
| Ferric oxide ($Fe_2O_3$) | 7.92 |
| Manganese oxide (MnO) | .26 |
| Lime (CaO) | 1.28 |
| Magnesia (MgO) | .73 |
| Sulphuric anhydride ($SO_3$) | .36 |
| Alkalies ($Na_2O$) | .19 |
| Alkalies ($K_2O$) | 1.71 |
| Water at 100° C | 1.83 |
| Ignition loss | 1.77 |
| | 100.27 |

This is a normal shale, scarcely as good as the shale last described and yet of fair quality. It has high silica and its combined aluminum and ferric oxide have the ratio to silica of 1 to 2.2. The percentage of sulphuric anhydride is too low to be detrimental.

## GYPSUM.

Gypsum, suitable for use as a set retarder of Portland cement, is reported to occur in the "Red Beds" south of Iron Mountain.

## ECONOMIC CONDITIONS.

A Portland cement plant at Iron Mountain should use for its raw materials the Graneros shale at the end of the Bradley spur and the Niobrara shaly limestone east of the same point. An extension of the Bradley spur one-quarter of a mile long would connect the two deposits. Chugwater Creek furnishes sufficient water for a mill on the railroad on its banks. Coal at Cheyenne is $4 to $5 a ton. To this price would necessarily be added the freight from Cheyenne to Iron Mountain on the Colorado and Southern Railroad. The fuel cost alone would approximate 40 cents a barrel, which is over one-half of the total cost of manufacturing a barrel of Portland cement in the East. It is possible, however, that coal coming over the Colorado and Southern Railroad from the north would be cheaper.

## COST OF A PORTLAND CEMENT PLANT.

It is perhaps worth while to add some general estimates of the cost of installing a Portland cement plant. The cost varies with the number of kilns constructed, although the proportional increase in cost is less with increase in the number of kilns. An 8-kiln plant, manufacturing 1,200 barrels of Portland cement in twenty-four hours, would cost from $360,000 to $400,000, while a 6-kiln plant would cost from $300,000 to $360,000.[a] Besides this first cost a large reserve capital is needed, since (1) each new plant during a period of experimentation makes cement that is below the grade required by contractors; (2) contractors are accustomed to use certain brands of Portland cement, and a new brand must establish a reputation before it can make large sales; (3) a Portland cement plant sells much of its product on long payments, but many of its own bills must be met at once. Mr. E. C. Eckel[b] further gives the following as an average cost per barrel at an 8-kiln plant, with 80-foot kilns, producing 2,000 barrels of Portland cement a day:

*Cost of Portland cement per barrel.*

| | |
|---|---|
| Cement materials | $0.08 |
| Power coal [c] | .08 |
| Drier coal [c] | .01 |
| Kiln coal [c] | .10 |
| Labor | .10 |
| Supplies, etc | .11 |
| Office and laboratory | .03 |
| Administration and sales | .05 |
| Interest, etc | .12 |
| | .68 |

In Wyoming the item of labor would be at least twice that here given, while at places near coal fields the item of fuel would be less by one-half, and for points distant from coal fields should be multiplied by two. It is therefore evident that Portland cement can be made in eastern Wyoming at a cost below the present local prices of eastern brands.

[a] Eckel, E. C., Cements, limes, and plasters, N. Y., 1905, p. 556.
[b] Ibid., p. 561.
[c] At $2 a ton.

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