Forestry, Charles C. Deam, State Forester.

Lands and Waters, Charles Goodwin Sauers, Acting Supt.

Fish and Game, George N. Mannfeld, Superintendent.

Further submitted report on Game Warden Service by the Director.

Information service by Charles Parrish.

Plan of cooperation suggested by Indiana Audubon Society.

Financial report by E. W. Gallagher, Accountant.

List of Publications.

## REPORT OF THE DIVISION OF GEOLOGY

W. N. LOGAN, State Geologist.

The geological force of the division as at present organized consists of:

W. N. LOGAN, Ph. D., Economic Geology.
E. R. CUMINGS, Ph. D., Stratigraphy and Paleontology.
C. A. MALOTT, Ph. D., Topography and Glaciology.
S. S. VISHER, Ph. D., Geography.
W. M. TUCKER, Ph. D., Hydrology.
J. R. REEVES, Assistant and Draftsman.
H. W. LEGGE, Preparator.

### OFFICE FORCE

LUTHER S. FERGUSON, A. B., Assistant Geologist and Supervisor of Natural Gas.
A. J. COLEMAN, Curator of Museum.
MISS ESSIE BOWLES, Clerk and Stenographer.

### FIELD CORPS FOR 1920

W. N. LOGAN
E. R. CUMINGS
C. A. MALOTT
J. R. REEVES
A. R. ADDINGTON
LUTHER S. FERGUSON
RALPH E. ESAREY
GLENN G. BARTLE
JOHN M. FLEEHART
MARSHALL A. HARRELL
O. H. HUGHES

### NATURAL GAS INSPECTION

*Deputies*

| | |
|---|---|
| C. N. BROWN | Geneva |
| JOHN ERSINGER | Sullivan |
| J. P. HORTON | Montpelier |
| W. T. LEE | Newcastle |
| GEO. F. MELTZER | Shelbyville |
| J. E. McINTYRE | Marion |
| HERSCHELL RINGO | Muncie |
| GEO. H. SMITH | Owensville |
| JOHN WATSON | Petersburg |
| HOWARD LEGGE | Bloomington |


Map showing distribution of geological resources of Indiana.

PUBLISHED REPORTS

Reports, books and papers were prepared and published by the Division of Geology during the year as follows:

"Kaolin of Indiana," publication No. 6, Conservation Department.

"Petroleum and Natural Gas in Indiana," publication No. 8, Conservation Department.

"Report of the Division of Geology," Year Book, 1919. Containing a report of the work and finances for the year and the following technical papers: "Indiana Kaolin," "Mineral Resources of Indiana: How They Are Utilized," "Minable Coal Under the Wabash River in Vigo County," "Waste in Coal Mining in Indiana," and "Topographic Mapping in Indiana."

"A map showing Distribution of Oil and Gas in Lndiana," Oil News. "On Licensing of Oil Geologists," Oil News. Also parts of "Turkey Run," and "One Hundred Years of Indiana's Resources."

OIL AND GAS REPORT

During the year a report of 279 pages on the subject of petroleum and natural gas was prepared and published. This report contains all of the information that was available at the time of going to press. It contains a discussion of the properties, origin, mode of occurrence, mode of accumulation, and methods of exploitation of petroleum and natural gas. It also contains a discussion of methods of prospecting, the value of surface indications, and the general geological conditions under which oil and gas accumulates in Indiana and reports of oil and gas conditions by counties. The report is accompanied by a geological map of the State, a map showing the distribution of oil and gas bearing areas, a map showing the position of the Trenton limestone with reference to sea-level and a large number of smaller maps. There are sixty-three illustrations.

KAOLIN REPORT

The "Kaolin of Indiana" was made the subject of a special report which was issued during the year. The report deals with the chemical and physical properties of the kaolin, its geological occurrence in the State, the theories of its origin, its distribution and possible means of utilization.

Beds of kaolin occur at the contact between Chester shales and the Mansfield sandstone and less abundantly at points of contact between Chester shales and sandstones. The report contains 131 pages and 43 illustrations. The demand for the report has been constant since its publication.

SUMMARY OF INDIANA GEOLOGY

Progress was made during the year on a handbook of information on the geological conditions and economic resources of Indiana. The necessity for such a volume occurs through the exhaustion of the supply of special reports on many phases of the geology of the State. The desire of many persons, particularly teachers and students, for a comprehensive report on the geology and natural mineral resources has created a strong demand for such a publication, and its preparation has been undertaken.

The preparation of the chapters on stratigraphy and paleontology is in charge of Dr. E. R. Cumings. The chapters on topography and glaciology are being prepared by Dr. C. A. Malott ,and the chapter on geography has been prepared by Dr. S. S. Visher. The chapters on economic geology have been prepared by the State Geologist. Two of these chapters have been published in order to give them an advanced and somewhat wider distribution. These are the chapters on kaolin, and oil and gas.

#### STATE FAIR EXHIBIT

On account of insufficient space the Division of Geology was unable to make a very creditable display at the State Fair. A small part of the building occupied by the Division of Fish and Game was available for our exhibit. It is hoped that better facilities may be afforded us in the near future.

Two assistants were present the entire period of the Fair to give information to those visitors who were interested in the natural resources of the State.

Samples of coal, oil shales, oil sands, clays, kaolin, and other minerals were on exhibition and the attention of the visitors was called to these resources and to the publications containing descriptions of them. Reports were distributed and information was given on many of the phases of Indiana's geology and raw materials.

#### INVESTIGATIONS OF OIL SHALE

Field work on the distribution of oil shale was continued during the year. The distribution and stratigraphical conditions of the New Albany shale were studied in the field and samples were collected and tested in the laboratory. Satisfactory progress was made in the investigation of these shales.

Samples of the carbonaceous shales overlying the coal beds in western and southwestern Indiana were collected and are being tested in the laboratory. The determination of the percentage of crude oil, gas, carbon, ash, potash and various by-products of crude oil are being determined. The results of these investigations will be presented in a published report as soon as the work is completed.

#### FIELD WORK

The summer season is devoted largely to field work and during the past season a study was made of the geology of the Clay City Quadrangle and counties or parts of counties adjacent. The territory embraced Clay, Sullivan, Vigo, Owen and Greene counties. The work included a study of the topography, stratigraphy, structural conditions and economic geology of the quadrangle and the adjacent territory.

The field party consisted of the following: W. N. Logan, C. A. Malott, John R. Reeves, Luther S. Ferguson, Ralph E. Esarey, Glen G. Bartle, John M. Fleehart, Marshall A. Harrell, A. R. Addington, and O. H. Hughes. Dr. E. R. Cumings studied the correlation of the Ordovician formations of Indiana, Ohio, and Kentucky, in the field.

In the coal area a large number of samples of coal, fire clay, and oil shales were collected for investigation in the laboratory. These investigations are being carried on as time from other duties permit.

In the New Albany shale W. N. Logan, and J. R. Reeves collected samples of shale from Floyd, Clark, Scott, Jefferson, Jennings, and Bartholomew counties. The percentage of crude oil contained in these shales is being determined and the number and percentage of its by-products.

A large number of field investigations for citizens of the State were undertaken and completed during the year. The work was done without expense to the Division, the expenses of the investigations being borne by the parties interested. Investigations of this character were made in the following counties: Bartholomew, Jennings, Jackson, Lawrence, Monroe, Greene, Clay, Putnam, Orange, Davies, Spencer, Washington, Warrick, Vanderburg, Brown, Hendricks, and Owen.

### LABORATORY DETERMINATIONS

Numerous rocks, minerals, coals, clays and other mineral substances were received during the year from citizens of the State with requests for determination as to value or possible usefulness. For the larger number of these samples it was possible to give the required information without expense to the citizen but in some instances the services of a chemist had to be secured and the expense borne by the individual seeking the information. Both qualitative and quantitative tests were made with a minimum of expense to the citizen. The following is a summary of the determinations made by the Division during the year.

| | |
|---|---|
| Coals | 53 |
| Clays | 60 |
| Shales | 31 |
| Sands | 8 |
| Water | 10 |
| Oil sands | 121 |
| Oil shales | 34 |
| Iron ores | 21 |
| Limestones | 42 |
| Pyrite | 34 |
| Oils | 8 |
| Miscellaneous minerals | 109 |
| Total | 531 |

Some of these determinations required many hours work in the preparation of the samples and for the necessary chemical reactions. The work requires part time of three men.

### NATURAL GAS SUPERVISION

The supervision of natural gas conservation is in charge of the Division of Geology. The Assistant Geologist acts as Supervisor of Natural Gas. The following are serving as deputies: C. N. Brown, Geneva; J. P. Horton, Montpelier; John Ersinger, Sullivan; W. T. Lee, Newcastle; Howard Legge, Bloomington; Geo. F. Meltzer, Shelbyville; Geo. W. Smith, Owensville; Hershell Ringo, Muncie, and John Watson, Petersburg.

During the year these inspectors inspected the plugging of 406 wells. Of these 209 were in the eastern Indiana oil field, 31 were in Sullivan county, 9 in Gibson county, 3 in Monroe county, one in Lawrence county, one in Jefferson county, two in Jennings and the remainder mainly in the southwestern part of the State.

For the inspection of these wells, 4,060 dollars were collected, 3,248 dollars were paid the inspectors and 812 dollars were turned into the funds of the Department as a partial offset to the office expenses incurred as a result of conducting the work.

### ASSISTANCE TO INDUSTRIAL COMPANIES

During the course of the year there was an active demand by industrial concerns for information in regard to Indiana's raw materials. There was a demand for locations of sand, gravel, building stone, coal, paint pigments, rock salt, fuller's earth, molding sands, refractory sands, kaolin, plastic clays, cement materials, oil and gas, and oil bearing shales. These companies were given assistance in the office, laboratory and field.

### MUSEUM

The collections in the museum were viewed by a large number of visitors notwithstanding the crowded condition existing there. The number of visitors registering during the year was 11,382 which was probably not over thirty per cent of the total number of visitors.

During the year donations were made to the museum by the following persons: F. M. Roller, Mrs. John Heim, Mrs. Black, W. D. Cost, Frank Hasselman, J. S. Klingsmith, H. E. Taylor, Lester Horton, and Geo. J. Dyer, Indianapolis; Albert A. Orth, Terre Haute; W. T. Selmier, Otto; Dr. Robt. F. Buehl, Richmond; C. W. Richards, Clarksville; B. F. Johnson, Edwardsport; George Bishop, Mitchell; and M. E. Edgerton, Jacksonville, Florida.

The National Association of Audubon Societies presented the museum with a collection of feathers from the Bird of Paradise, these feathers having been confiscated by custom house officials. Specimens of fish and game were donated by the Division of Fish and Game. A souvenir from the big German gun, Big Bertha, was presented by General Harry Smith who had received it from Bert A. Boyd.

A collection of Indian relics was purchased from Theo. L. Dickerson estate, of Brookville, Indiana. The collection contains 100 axes, 80 pestles, 600 arrow heads and a number of knives and other implements.

Loans. A model of the John McCormick homestead of 1820, present site of Indianapolis, was loaned by John Q. Adams of Indianapolis. A collection of war relics were loaned by J. E. Kimmel of Lafayette and W. G. Shirley, of Indianapolis. Loans were also received from Mrs. Neva Youse, Dr. Geo. Bruce, Chas. E. Jay and F. H. Smock, Indianapolis.

New museum cases are very much needed to properly display the collections, the old cases being so badly out of repair that the collections cannot be adequately protected and the expense of repairing being equal to the cost of new modern cases. Additional space for the collections is very much needed as any one who has visied the museum can testify.

A catalogue of the specimens in the museum is being made and will be published, it is hoped, at an early date.

### OFFICE WORK

The greater part of the time of the Assistant Geologist and the Stenographer is occupied by the routine office work. This work consists of the answering of letters which request information concerning some phase of our economic resources, of sending out reports where such information is contained in available reports, and in conferences with parties who come to the office for information. Other duties include work on reports, cataloguing well records, inspection of the plugging of wells which cannot be reached by the deputy inspectors, proof reading, and attending to the bookkeeping and other clerical work of the Division.

The following is a summary of the office work as far as it can be classified for the year ending September 30, 1920:

| | At Office | At Laboratory | Total |
|---|---|---|---|
| Letters received | 2,320 | 250 | 2,570 |
| Letters mailed out | 2,889 | 251 | 3,130 |
| Geological reports distributed | 1,856 | 34 | 1,890 |
| Geological maps distributed | 247 | | 247 |
| Personal conferences held | 648 | 324 | 972 |

## THE BUILDING STONES OF INDIANA

W. N. LOGAN, State Geologist

Building stones usually include those used in the construction of edifices, those used for ornamental purposes in construction, and those used for roofing, flagging and curbing.

The kinds of rock included under building stones are varieties of the three great divisions of rocks, sedimentary, igneous and metamorphic. The only igneous and metamorphic rocks in Indiana are those occurring in the glacial drift. The boulders of igneous and metomorphic rock are frequently used for interior and exterior rubble-work in the glaciated area of the State. The main supply of building stone in Indiana is obtained from the sedimentary division of rocks.

*Properties of Building Stones.* The value of a stone for building purposes depends upon its chemical and physical properties. Color is one of the important properties of building stones. Permanency and uniformity of color are very desirable qualities. A stone may have a very pleasing color in the quarry and change to a very different one when placed in a structure. The color may be in the constituent grains or in the cementing material which binds the grains together. Sedimentary rocks often contain oxides of iron which produce red, yellow or buff colors.

A good building stone must have two kinds of strength. It must have compressive or crushing strength so that it can withstand the weight placed upon it without crumbling. The stone must also have transverse strength so that when it is supported at each end and weighed in the middle as in window and door sills, it will not break.

A good building stone should have a low porosity so that it will not absorb much water and thus will be better able to resist the action of frost.

A building stone should have good resistance to heat. It should not crumble easily under the temperatures of ordinary fires. It should also be able to withstand sudden changes of temperature so that if its temperature is raised suddenly and then suddenly lowered the stone will not crumble.

The chemical analysis may reveal little concerning the value of a building stone. The presence of minerals which may produce detrimental colors during weathering may be revealed, and whether the stone should be classed as calcareous, silicious, ferruginous or argillaceous.

The life of a building stone depends upon the climatic conditions of the region in which it is used. The same stone will last for a much longer period in a dry climate than in a humid climate. Its length of life will also be determined by its position in the structure. A porous rock in the foundation will have a much shorter life than when placed higher in the wall.

### GEOLOGY OF INDIANA BUILDING STONE

*The Ordovician Limestones.* These are generally thin and irregularly bedded limestones. Serviceable in some outcrops for building purposes and flags, but not contributing largely to our supplies of good building stone. The Ordovician limestones outcrop in the counties in the southeastern portion of the State. The position of outcrop is indicated on the geological map.

Silurian limestone (Niagara) is widely distributed in Indiana Its outcrop is largely concealed in the north central and eastern Indiana by glacial drift. In the southeastern portion of the State it is exposed in many places.

The unweathered stone is often blue in color but white on weathered surfaces. It is generally thinly bedded and is much used for curbing, guttering and flagging. It has also been used for structural purposes in buildings and bridges. The Silurian limestone has been quarried at the following points: Anderson, Alexandria, Bluffton, Buena Vista, Delphi, Eaton, Greensburg, Harper, Holton, Huntington, Kokomo, Laurel, Longwood, Marion, Markle, Montpelier, Newpoint, Osgood, Peru, Sardina, St. Paul and Westport.

Devonian limestones occur both north and south of the Silurian area. The limestones are thin bedded and often blue in color. They have been used for macadam, rubble, curbing, flagging and bridge piers. They have been quarried at Decatur, Logansport, North Vernon, Speed and other places.

Mississippian limestones. The Mississippian system of rocks in Indiana contain a wealth of good building stone. The divisions whch contain limestones are the Harrodsburg (Warsaw) the Salem (Oolitic), the Reesville, the Beech Creek, the Golconda and the Glenn Dean.

The Harrodsburg limestone overlies the Knobstone shales and sandstones, and underlies the Salem when that formation is present. It is often thin and irregularly bedded but beds of three or more feet in thickness are not uncommon. It is often very fossiliferous containing crinoid stems and bryozoans. It has been used locally for building purposes but has had a more extended use for rubble and macadam. Its high calcium carbonate content makes it desirable for the manufacture of lime and cement. For its distribution see the accompanying geological map.

The most widely used and widely known of the Mississippian limestones of Indiana is the Salem, or Indiana Oolitic. This is the most widely used limestone for building purposes in the United States. The demands for it are constantly increasing.

BUILDING STONES

Indiana Oolitic. The superior qualities of the Oolitic limestone of Indiana are now widely recognized. It is a medium fine-grained stone with even texture, composed of minute shells, the fragments of shells and concretionary grains (Oolitic) cemented by calcite. When first taken from the quarry it is soft and easily carved, but under the action of atmospheric agents accompanied by the loss of quarry water, it becomes harder.

Composition. The Indiana Oolitic consists essentially of calcium carbonate which rarely falls below ninety-eight per cent, and ranges even higher than ninety-nine. It also contains on the average more than three-quarters of a per cent of magnesium carbonate, a small amount of iron, probably in the form of a sulphide, and a small amount of insoluble matter, largely silica. A detailed quantitative analysis reveals traces of minute quantities of other elements such as aluminum, carbon, phosphorus, sodium and sulphur. Some compounds formed from these elements would be detrimental if they occurred in sufficient quantities but this rarely ever happens. The iron present is partly in the form of minute crystals of pyrite which are widely distributed through the rock. Rarely are they so concentrated as to form blotches by their oxidation.

Color. The color of the limestone varies through the shades of buff, gray and blue. The prevailing color in the oxidized zone above the level of ground water is blue. Gray shades occur both above and below the level of ground water. The blue color is due to the presence of compounds which are oxidized in the zone of weathering, the oxidation producing the buff color which is permanent in so far as any change in the constituent materials of the stone is concerned. The compounds present in the blue stone which are oxidized are probably compounds of iron and of organic matter. The oxygen is carried into the stone by ground waters which were originally meteoric and in that state secured their oxygen. Since the level of ground water is a vacillating irregular line, and the penetration of oxygen carrying waters was greater at some points than others and the amount of oxygen carried was variable the line of contact between buff and blue is a very irregular one. It requires only a short period of time for stones of slightly different colors to assume the same hue after being placed in a building. Light buff and deep blue stones may be used in the same building if care is taken to select the proper blending and avoid the juxtaposition of strong contracts.

Texture. The Oolitic limestone is composed of shells, fragments of shells and true Oolites. These constitute the grains of the stone. These grains were deposited under sea water, the size and uniformity of the grain being dependent upon the sorting action of the water. In the quieter waters small grains of fairly uniform size were deposited. Where currents prevailed, larger particles were deposited, and where currents were shifting, fine and coarse grains succeeded each other in rapid succession. The finer particles consist largely of the shells of foraminifera which are spherical, conical or disc shaped. Around some of these shells there are concentric layers of calcium carbonate, thus forming a pseud-oolite. There are also true oolites present but the number is not large.

In the coarser varieties of stone larger shells or fragments of shells are present. Bryozoans, brachiopods, gastropods and other fossil forms predominate over the foraminifera. These are generally young forms of small size but occasionally a large form is present both valves being present and closed, indicating that it was probably floated to its position due to its hollow condition.

The shells are composed of calcium carbonate and are cemented together with crystals of the same mineral. The value of the stone for building purposes is greatly enhanced by the proper balance between the softer grains and the harder cement.

Porosity. The property of having pores, minute spaces not filled with mineral matter is possessed by most rocks. In the Oolitic stone both visible or macroscopic and invisible or microscopic pores exist. The percentage of pore space varies with the size, shape and arrangement of the grains. The pores, both visible and invisible, are of irregular shape and are due to incomplete cementation in part and in part to cavities in the interior of shells. There are bands of stone in which cementation has been carried to a more perfect state resulting in high density and minor porosity. In such instances circulating water carrying calcium carbonate derived from upper layers have been the agents of cementation. Porosity decreases the weight of a stone and excess porosity decreases its strength. It is also a measure of its absorptive power and in a measure its resistance to frost.

Absorption. The porosity of a stone is measured by the quantity of water it will absorb. The ratio of absorption is the ratio between the weight of the stone and the weight of the water absorbed. The ratio of absorption ranges from 1.13 to 1.95 in the Indiana Oolitic. The resistance of a stone to frost action depends upon its absorptive power. The more water a stone absorbs the greater the disrupting effect when the water freezes in the pores of the rocks.

Specific Gravity. The specific gravity of the air-dried Oolitic stone varies between 2.25 and 2.65. The average of a large number of samples determined by the writer gave a specific gravity of 2.45. The specific gravity of the unseasoned stone is higher, being nearer 3. The shipping weight of the stone is estimated at from 175 to 185 pounds per cubic foot. The actual weight per cubic foot may be determined by multiplying the specific gravity of the stone by the weight of a cubic foot of water (62½ pounds).

Crushing Strength. The compression or crushing strength of a stone is measured in terms of load per square inch of surface required to crush the stone. Tests made upon samples of Indiana Oolitic limestone indicate that its crushing strength ranges from 4,000 to 10,000 pounds per square inch. The stone of the minimum strength would sustain a wall constructed of Oolitic stone to a height of 329 feet and the stone of maximum strength, a wall of 822 feet high.

Transverse Strength. The transverse or cross-breaking strength of a building stone is measured in terms of the modulus of rupture which is the weight necessary to break a bar of one inch cross section when resting on supports one inch apart, the weight being applied in the middle. The load required to produce rupture in the Oolitic stone varies from 81 to 130 pounds. The transverse strength of the stone is sufficient to meet ordinary structural conditions. Cross-breaking is produced by defferential settling of structures and where this is excessive, few stones are able to resist it.

Resistance to Heat. Building stones are sometimes subjected to high temperatures and should be able to withstand not only the heat but the contractional effects of sudden cooling. The failure of a stone may be due to the failure of the individual grains or to the failure of the cement. The grains and the cement of the Oolitic stone are each composed of calcium carbonate and there is probably little difference in the temperature required to produce failure in these two constituent parts of the stone. At a temperature varying between 800° and 1000° limestone is converted into lime and this is the temperature required to produce complete failure in the Oolitic stone. Water suddenly thrown upon the stone when heated to a temperature of approximately 1000° F only caused a slight crumling of the stone. It may be said that the Indiana Oolitic has as great fire-resisting properties as any stone of similar composition and higher resistance than many limestones.

Resistance to Frost. The power of a stone to resist frost action depends upon its composition, structure and density. These properties all affect the amount of absorption of the stone. The higher the amount of clay or organic matter contained in a stone the more easily it is affected by frost action. A layered rock resists frost action less easily than one of homogenous structure. The greater the density of the stone the more easily it resists the action of frost. Being of fairly uniform composition and homogenous in structure the property of resisting frost in the Indiana Oolitic is dependent upon its density of porosity, which is somewhat variable.

Distribution. The outcrop of the Salem formation which contains the Indiana Oolitic limestone extends from Putnam County southward to the Ohio River. The belt extends through Putnam, Owen, Monroe, Lawrence, Washington and Harrison counties. The width of the outcrop varies from a few rods to fifteen miles. Quarries of the Oolitic stone occur near Romona, Stinesville, Ellettsville, Hunter Valley, Bloomington. Clear Creek, Sanders, Oolitic, Bedford, Salem, Corydon, and Georgetown. The main quarry district lies in Lawrence and Monroe counties, extending from Stinesville to Bedford. Seventy-six large quarries are located in these two counties and supply fifty-five mills which mill between ten and twenty million cubic feet per year.

The Salem limestone dips southwestward at the ratio of about thirty-five feet to the mile. At a short distance from the outcrop the bed passes under an overburden of Mitchell and Chester rocks too heavy to be removed. So quarrying is confined at the present time to the outcrop and to places where the overburden is thin. When these areas are exhausted sub-surface quarrying will doubtless be undertaken.

Mitchell Limestone. Overlying the Salem limestone is the bedded Mitchell limestone. The layers of this stone vary in thickness from a few inches to four feet. Perhaps on the average the layers range from one to two feet. The stone is harder than the Salem and in some zones contains much chert. It furnishes a very serviceable building stone and is especially well adapted for basements and foundations, as it resists frost action well. It is one of the best limestones in the United States for macadam and has had an extensive use in Indiana for this purpose. It has also been used extensively in the manufacture of lime and Portland cement. It has been quarried at many points along its area of outcrop. It has been quarried and used extensively in buildings at Spencer. Other quarries are located at Bedford, Bloomington, Corydon, Abydell, Milltown, Mitchell, Greencastle, Putnamville, Marengo and Salem. Many quarries are located convenient to highways which are to be macadamed, the length of haul determining in most cases the location of the quarry. The distribution of the Mitchell is indicated on the geological map.

Chester Limestones. Overlying the Mitchell in Indiana is a series of interstratified limestones, sandstones and shales of Chester age. The lowermost bed of limestone, the Beaver Bend, is a cream-colored Oolitic limestone, varying from massive in some outcrops to thin bedded in others. Its thickness is usually about ten to fourteen feet, though in places it attains more than twenty feet. It may be used for rubble, macadam and lime.

The Reelsville is usually about four feet thick, but attains a thickness of ten feet. It is generally pyritiferous and on that account and because of its thinness is of limited usefulness.

The Beech Creek limestone is normally about fifteen feet thick, but attains in places a thickness of twenty-five feet. It is usually jointed, breaking up into cubical blocks. It is usually massive, but sometimes thin bedded. The limestone has been used for rubble, macadam and burned locally for lime.

The Golconda limestone is coarsely crystalline in the lower part and Oolitic in the upper portion. It generally occurs in two ledges, which are separated by a stratum of shale. It attains a thickness of thirty feet. It has been used locally for building, rubble, and macadam. The Glen Dean is the uppermost Chester limestone and occurs only very locally.

The Chester limestones have been used locally in Owen, Greene, Monroe, Lawrence, Martin, Orange, Crawford and Perry counties.

Pennsylvania Limestones. Beds of limestone are interstratified with beds of shale, sandstone and coal in the coal measures of Indiana. These limestones are usually irregularly and thinly bedded. They are serviceable locally for the cruder structural purposes and for concrete and macadam. One of these has been quarried near Farmersburg.

### SANDSTONES FOR BUILDING

There are a number of geological formations in Indiana which contain sandstones suitable for structural uses. The St. Peters sandstone lies too deeply buried to be utilized in Indiana. The Pendleton sandstone of the Devonian outcrops in a few places and is used for structural purposes and glass sand.

The Mississippian rocks contain a number of sandstones, some of which are suitable for structural purposes. The Knobstone contains ledges of sandstone which are thick enough and sufficiently indurated to be serviceable for building purposes. The sandstone from the Riverside division of the Knobstone has been quarried at St. Anthony, near New Albany, and at

Riverside. It has served a local demand in a number of places within the area of its outcrop.

The Chester division of the Mississippian contains a number of sandstones which are locally useful for structural purposes. The Brandy Run sandstone, which lies between the Beaver Bend limestone and the Reelsville limestone, is in many places only a sandy shale or a thin bedded, fissile sandstone, but in places ledges of indurated sandstone occur.

The Elwren sandstone, which occupies the interval between the Reelsville limestone and the Beech Creek limestone, is like the Brandy Run, shaley in places and not often sufficiently indurated for good building stone.

The Cypress sandstone lies upon the Beech Creek limestone and is more uniform in thickness and properties than any of the other Chester sandstones. Indurated ledges of good structural qualities are of common occurrence. The Hardinsburg and the Tar Springs are other sandstones of the Chester which exhibit local phases suitable for building stone. The Chester sandstones have been quarried at Cannelton, Fountain, Williamsport and other places.

Pennsylvanian Sandstones. The principal sandstone occurs at the base of the coal measures and is called the Mansfield. In places it forms a basal conglomerate which has an iron oxide cement. In many places it contains ledges of iron stone which are suitable for building purposes. It varies in thickness from a few feet to two hundred feet. It has been quarried at Mansfield, Attica, Pottsville, Shoals and other places.

The Coal Measures contain other sandstones which are useful for structural purposes and are used locally. Such sandstones have been quarried at Madison, Jasper and other places. One such sandstone is the Merom, occurring in the southwestern part of the State.

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## CEMENT MATERIALS AND INDUSTRIES

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W. N. LOGAN, State Geologist.

### CEMENT

Cement is a calcined or cinerated material which has the property of setting when mixed with water and of hardening in the air or under water.

The class of cements which harden only in the air are called simple cements, and those which will harden under water are called complex cements.

Simple Cements. Simple cements are calcined materials, which may be divided into two classes: 1. Hydrate cements, which are manufactured from gypsum by driving off a part of its water of crystallization. They include such cements as plaster of paris, Keene's cement, Parian cement, and cement plaster. They differ from each other in the addition of small amounts of sand, limestone and clay, and in slight variations in methods of manufacture. 2. Carbonate cements. These consist of quick limes produced by calcination from various varieties of limestone, marble or dolomite, the temperature of decarbonation being reached in the process.

Complex Cements. These are cements, the materials of which have been subjected to temperatures high enough to form new chemical compounds. Four classes have been suggested: (a) Natural cements include such brands as Roman and Rosendale cements, which are manufactured by burning a silico-aluminous limestone at a temperature between decarbonation and clinkering. They exhibit no free lime, possess hydraulic properties, and do not slack unless ground very fine. They are of lighter weight, burn at lower temperatures, set quicker, have less ultimate strength, greater variation in composition and usually contain a higher per cent of magnesia than Portland cement.

The composition of the silico-aluminous limestones from which natural cements are derived are of variable constituents, varying between moderately wide limits—the Silica from 9 to 25 per cent; alumina from 1.5 to 1.; ferric oxide from 1.34 to 6.30; lime from 22 to 36; magnesia from 2 to 18; potash and soda from 1 to 6; sulphur trioxide from 1 to 2; volatile matter ($CO_2+H_2O$) 32 to 34 per cent.

The Devonian limestones of southeastern Indiana have been used extensively in the manufacture of natural cement, but production has fallen off until at the present time it is being produced at only one plant.

(b) Hydraulic Limes. These cements are manufactured by burning a silicious limestone at a temperature a little above decarbonation. They are of a yellowish tint and contain considerable free lime. They set slowly and have little strength in the neat, but are of greater strength when mixed with sand. They are of little economic importance in the United States.

(c) Pozzuolan Cements. Cements of this class are made from an uncalcined mixture of slaked lime and a silico-aluminous substance such as volcanic ash or blast-furnace slag. The composition of the mixture may vary between the following limits: Silica, 52 to 60 per cent; alumina, 9 to 21 per cent; ferric oxide, 5 to 22 per cent; lime, 2 to 10 per cent; magnesia, 0 to 2 per cent; potash and soda, 3 to 16 per cent; moisture, 0 to 12 per cent. Cements of this type are manufactured in Ohio and Alabama.

(d) Portland Cement. Portland cement is the product obtained from burning at a high temperature an artificial mixture of calcareous and silico-aluminous rocks or slags. The mixture consists essentially of lime, silica, alumina, and oxide of iron, though small quantities of magnesia and other compounds are usually present. It was first manufactured in England and so named because of its resemblance to the Portland building stone of that country.

Raw Materials. The raw materials used in the manufacture of Portland cement vary widely in physical and chemical characteristics. In the selection of materials the attempt is usually made to select for one constituent a rock high in calcium carbonate content and for the other one highly aluminous in composition. The mixture may be marl and clay; limestone and clay or shale; chalk and clay or shale; pure limestone and argillaceous limestone or limestone and slag. Sometimes it is desirable to mix two limestones if one contains too high a per cent of magnesia, but is so situated in the quarry as to make its use essential to economy. It is also desirable in some plants to mix two kinds of shale, say a highly silicious with a highly aluminous one. In Indiana the raw materials used in the manufacture of Portland cement are marl and clay, shale and limestone, and slag and limestone.

Quarrying Raw Materials. When surface clays are used the open pit method is employed for securing the clay, which is loaded by steam shovels on cars for transportation to the plant. The marl is taken from the bottom of the lakes by steam dredges.

The shale is taken from the face of an outcrop by blasting down the shale and loading it on cars by the use of steam shovels. The limestone is obtained from the outcrop of a ledge of considerable thickness. Holes about six inches in diameter are drilled about ten feet back from the face of the quarry at intervals of twelve or fourteen feet to the depth of the quarry, which is often sixty feet or more. Each of these holes is charged at top and bottom with from 300 to 350 pounds of blasting powder. The larger blocks of limestone are drilled and broken up with explosives and the smaller masses loaded on cars by the use of steam shovels.

Crushing and Grinding. The limestone is crushed first in large rotary crushers, then in small ones.

The crushed limestone and shale are dried in horizontal cylindrical ovens and then weighed and mixed in a proportion depending upon the chemical composition of the limestone and shale.

The mixture is first ground in a tube mill until it is fine enough to pass through a sieve of 65 meshes to the inch and then in a ball mill until it passes a 95-mesh sieve.

Burning. The pulverized materials are burned in horizontal cylindrical revolving kilns which are constructed of steel shell lined with fire brick. The kiln is placed on a slant and the raw material is admitted at the stack or higher end, and works its way downward toward the lower end, where the flames of the kiln are fed by crushed coal under an air pressure of 55 pounds per square inch. The temperature attained is from 2,000 to 2,500 degrees F., which is sufficient to convert the raw material into a clinker. The clinker drops through an opening in the lower end of the kiln into a pit, from which it is elevated into a vertical cylinder, where it is cooled. Gypsum is added and it is ground until it is fine enough to pass a 250-mesh sieve. Being elevated to storage bins, it is then weighed and sacked at one operation. This is the dry process used in most of the plants in Indiana. The wet process is described under the discussion of the Indiana Portland Cement Company.

## CEMENT

Raw Materials. The raw materials for the manufacture of cement are widely distributed in Indiana. The formations which contain suitable materials range in age from the Ordovician to the Pleistocene. The outcrop of these materials cover a large area in the State and the materials are easily accessible to transportation facilities and to fuel supplies. Many small streams and a few large ones cross the outcrop of the raw materials and from these a sufficient water supply may be obtained.

Ordovician Limestones and Shales. Limestones of this age attain a thickness of thirty feet or more in a single ledge in the southeastern portion of Indiana. Excellent outcrops occur in Clark and Jefferson counties. The limestone is often argillaceous, but in many places is a soft calcareous stone of whitish color. Associated with the Ordovician limestones are beds of shale, which in places are highly calcareous, in other places silicious. There is little doubt that in these limestones and shales there are the proper materials for the manufacture of Portland cement. Chemically some of the limestones contain more than 90 per cent of the carbonates of calcium and magnesium, the latter varying from 6 to 10 per cent.

Silurian Limestones and Shales. The Silurian limestones form the bed rock of a large area in the southeastern, eastern and north central portions of Indiana. Much of the limestone of this age in the eastern and north central portions of the State contain too high a magnesia content to be exercised in selecting a location. Shales of a calcareous nature are to be found associated with these limestones and Ordovician and Mississippian shales are near at hand.

Devonian Limestones. Devonian limestones suitable for the manufacture of both natural and Portland cement, outcrop in southeastern Indiana. These Devonian limestones attain a thickness of ninety feet. They outcrop near beds of shale of Mississippian age, which may be used to obtain the proper Portland cement mixture. The Devonian limestones are being used in the manufacture of natural and Portland cement at Speed and the New Providence shales of the Mississippian to form the mixture for the latter.

Mississippian Limestones. The Mississippian rocks of Indiana occupy a large area of outcrop in Indiana and their strata contains an inexhaustible supply of excellent materials for the manufacture of Portland cement.

Limestones. The limestones of the Mississippian which are suitable for use in the manufacture of Portland cement may be grouped under the Harrodsburg (Warsaw), the Salem (Oolitic), the Mitchell and the Chester. The Harrodsburg, the oldest and lowermost member of this group of limestones, attains a thickness of 150 feet. It is a highly calcareous limestone suitable for use in the manufacture of Portland cement. Overlying the Harrodsburg is the Salem limestone, which is of high calcium carbonate composition and an excellent building stone. Only the grades of this stone unsuited to building purposes and the waste from the quarries should be used for cement. The thickness of the Salem lies usually between forty and one hundred feet. The percentage of calcium carbonate in the Salem frequently runs as high as 98 per cent and one per cent or more of magnesium carbonate and less than 1 per cent of silica, iron and alumina.

The Mitchell limestone which overlies the Salem where both are present is a compact bedded stone which attains in places a thickness of two or three hundred feet. This limestone contains a higher per cent of magnesia than the Salem, but rarely sufficient to render it unsuited to the manufacture of cement. It is being used at present in the manufacture of Portland cement at Limedale and at Mitchell, a form of utilization for which it is well suited. It is also valuable in the manufacture of lime and for road metal.

The Chester division of the Mississippian contains a number of limestones such as the Beaver Bend, the Beach Creek and the Golconda, which could be used in the manufacture of Portland cement. These beds range in thickness from ten to thirty feet. Because of the nearness of these limestones to the thicker beds of the lower horizon the necessity for their use will probably not arise except in very isolated instances. Their high carbonate content, freedom from detrimental impurities and nearness to excellent beds of shale warrant their consideration if greater nearness to fuel supplies or other considerations should suggest their use.

Mississippian Shales. The Mississippian formations contain an abundance of shales suitable for use in the manufacture of Portland cement. They are as widely distributed as the limestones of that period and are within easy reach of their outcrop. These shales may be grouped under the Knobstone and the Chester divisions.

Knobstone Shales. These shales lie below the Harrodsburg limestone and their outcrop lies parallel with the outcrop of the Harrodsburg and the succeeding limestone and at accessible distances from these limestones. The Knobstone shale contains facies which are highly arenaceous in character and others which are highly aluminous. In securing the proper mixture for the Portland cement it is desirable to use a certain portion of each of these shales. The shales are being used in the Lehigh plant at Mitchell and the plant at Speed in the manufacture of Portland cement.

Chester Shales. Shales occur in the Chester at the horizon of the Brandy Run, the Elwren, the Golconda, the Hardinsburg, the Indian Springs and the Buffalo Wallow. These shales vary in thickness from ten to forty feet and some of them are in places wholly replaced by sandstone. Both aluminous and arenaceous facies of the shales prevail so that it is not a difficult matter to make selections for the proper mixture. These shales are being used by the plant located at Limedale.

Pleistocene and Post Pleistocene Marls. The glacial lake basins of northern Indiana contain large quantities of marl, the calcareous secretion of the plant chara. This marl is essentially calcium carbonate, containing small quantities of magnesium carbonate, iron carbonate, silica, alumina and organic matter. An analysis of a sample of the marl is given as follows:

ANALYSIS OF SAMPLE OF MARL FROM JAMES LAKE

| | |
|---|---|
| Calcium carbonate | 92.41 |
| Magnesium carbonate | 2.38 |
| Calcium sulphate | .15 |
| Ferric oxide | .29 |
| Insoluble (silica, etc.) | 1.16 |
| Organic matter | 1.97 |
| Total | 98.36 |

Workable deposits of marl occur in lake basins in counties in the northern part of Indiana for the distribution of which see the article on marl in this report.

Pleistocene and Post Pleistocene Clays. Near the beds of marls in the northern part of Indiana there are beds of clay of Pleistocene and Post Pleistocene age, which are adapted to use in cement mixtures. The average of the analyses of eight samples of glacial clay which was used by the Wabash Cement Company is given by Oglesbey as follows:

ANALYSIS OF PLEISTOCENE CLAY

| | |
|---|---|
| Silica ($SiO_2$) | 56.74 |
| Alumina ($Al_2O_3$) | 19.43 |
| Ferric oxide ($Fe_2O_3$) | 4.83 |
| Lime (CaO) | 7.27 |
| Magnesia (MgO) | 3.05 |
| Loss on ignition | 10.39 |
| Total | 101.71 |

Furnace Slag. From the iron smelters in Indiana a large supply of slag is obtained which could be used in the manufacture of Pozzuolan cement, which is made from granulated blast furnace slag ground with dried quicklime or hydrated lime. The blast furnace slag may also be used in the manufacture of Portland cement, in which the slag takes the place of the silico-aluminous material of the shale. Ground limestone, instead of quicklime, is mixed with slag and the mixture cinderated. The Universal Cement plant at Buffington uses slag from furnaces of the Illinois Steel Company.

CEMENT PLANTS

*Indiana Portland Cement Company.* The plant of this company is located south of the Vandalia and Monon station at Limedale, near Greencastle. The plant began operations in 1919. The raw materials used are Mitchell limestone 78 per cent, Chester or Allegheny shale 11 per cent, and surface clay 11 per cent. The capacity of the plant is 1,200 to 1,500 bbls. per day. The process used is the wet process. The limestone and shale are crushed in gyratory crushers. The clay is disintegrated in the wash-mill. The clay slurry, crushed shale and limestone are passed through the kominuter and then through a vertical rotary screen into the tube mill. After being ground in the tube mill the slurry is discharged to correcting basins, from which it goes to the mixing basin. From the mixing basin it goes to the storage basin and from that through the feed tank into the rotory kiln, which has a length of 240 feet and a diameter of 10 feet. The clinker produced in the kiln is cooled in a rotary cooler, ground in a kominuter and tube mill and stored in concrete storage, being of the silo type. The following table shows the composition of the raw materials and the product as furnished by the president of the company, Mr. Adam H. Beck:

| | Clay. | Shale. | Limestone. | Cement. |
|---|---|---|---|---|
| Loss on ignition | 7.23 | 12.41 | 43.44 | 1.65 |
| Silica ($SiO_2$) | 71.77 | 51.32 | 1.88 | 22.32 |
| Alumina ($Al_2O_3$) | 12.10 | 23.53 | .25 | 6.19 |
| Ferric oxide ($Fe_2O_3$) | 4.62 | 7.21 | .29 | 3.27 |
| Lime (CaO) | .80 | .35 | 53.99 | 63.01 |
| Magnesia (MgO) | 1.00 | 1.60 | .44 | .90 |
| Sulphur trioxide ($SO_3$) | .... | .... | .... | 1.53 |

*Lehigh Portland Cement Company.* A large plant of this company is located at Mitchell. The plant consists of two 10-kiln units and has a total capacity of two and a quarter million barrels of cement per year. The raw materials consist of the Mitchell limestone and two varieties of Knobstone shale, one a silicious and the other an aluminous variety. The limestone used runs high in calcium carbonate, rarely falling below 96 per cent.

The limestone is first crushed in large gyratory crushers, then in smaller ones. The crushed limestone and shale are dried in horizontal rotary ovens, then weighed and mixed. The mixture is ground in a tube mill until it is fine enough to pass through a sieve of 65 meshes to the inch, then in a ball mill until it passes a 95-mesh screen. The pulverized mixture is burned in rotary kilns, which are fired with powdered coal under pressure. The clinker formed is cooled in vertical cooling cylinders. Gypsum is added and the clinker ground, stored and sacked.

*Louisville Cement Company.* The plant of this company is located at Speeds, near Sellersburg, in Clark County. The raw materials used consist of hydraulic limestone of Devonian age and Knobstone (New Providence) shale of Mississippian age. The limestone quarry is located near the plant, but the shale is brought from a distance. The company manufactures a considerable amount of natural cement, but the larger part of its product is Portland cement. The production of the former for 1919 was 300,000 bbls., and of the latter 800,000 bbls.

The composition of the raw materials and the finished product of the Portland cement is given in the following table:

| Constituent. | Limestone. | Shale. | Raw Mix. | Portland Cement. |
|---|---|---|---|---|
| Silica ($SiO_2$) | 4.78 | 65.54 | 14.94 | 21.32 |
| Alumina, etc. ($Al_2O_3$) | 1.38 | 23.52 | 6.34 | 8.78 |
| Cal. Carb. ($CaCO_3$) | 91.25 | .... | .... | .... |
| Calcium oxide (CaO) | .... | 1.67 | 41.85 | 63.26 |
| Magnesia (MgO) | 2.59 | 5.00 | 1.94 | 3.72 |
| Loss on ignition | .... | .... | 34.93 | .94 |
| Undetermined | .... | .27 | .... | .... |
| Insoluble Res. | .... | .... | .... | .42 |
| Sulphur trioxide ($SO_3$) | .... | .... | .... | 1.56 |

The composition of the hydraulic limestone and the natural cement is given as follows:

| Constituent. | Natural Cement Rock. | Natural Cement. |
|---|---|---|
| Silica ($SiO_2$) | 19.02 | 21.92 |
| Alumina, etc., ($Al_2O_3$) | .98 | 9.42 |
| Lime (CaO) | 34.68 | 47.63 |
| Magnesia (MgO) | 8.47 | 12.47 |
| Loss on ignition | 36.85 | 8.56 |

*Syracuse Plant of the Sandusky Cement Company.* This plant was established in 1900 and continued in operation for eighteen years. It was shut down in 1919, but resumed operation in 1920. The materials used during the first period of operation of the plant were marls taken from Lakes Syracuse and Wawasee and clay from near Lapaz, about thirty miles west of the plant at Syracuse. The composition of these raw materials and the product is given in the twenty-fifth annual report of the Indiana Survey as follows, by S. B. Newberry:

| | Marl. | Clay. | Cement. |
|---|---|---|---|
| Silicia | 1.74 | 55.27 | 22.06 |
| Alumina | .90 | 10.20 | 4.80 |
| Iron oxide | .28 | 3.40 | 1.66 |
| Lime. | 49.84 | 9.12 | 65.44 |
| Magnesia | 1.75 | 5.73 | 3.82 |
| Sulphur trioxide ($SO_3$) | 1.12 | .... | 0.90 |
| Loss | 46.01 | .... | .... |

The marl contained organic matter, making necessary the use of a large quantity of water to form a slurry. The expense of removing the extra water in burning rendered it difficult for the manufactured cement to compete with that produced by cheaper methods. Owing to labor conditions and other difficulties the plant was run at a loss during 1917 and 1918. Arrangements have been made for using limestone from Logansport and the proper machinery has been installed for grinding this raw material. The capacity of the plant is about 50,000 bbls. per month.

*Universal Portland Cement Company.* The plant of this company is located at Buffington. The plant has three separate producing units, Mills 3, 4 and 6. Power is supplied by transmission lines from Gary and South Chicago and from the waste heat power plant at Buffington, 12,000 K W by the former and 8,000 by the latter. Coal is used for fuel, that which is used in the kilns being pulverized.

Kilns of Mills Nos. 4 and 6 are equipped with Cottrell dust precipitators, using energy transformed and rectified to 65,000 volts direct current. The efficiency of these collectors is more than 90 per cent, and dust collected per kiln per hour is about 1,000 pounds.

Raw materials used in manufacture are granulated slag obtained from the blast furnaces of the Illinois Steel Company and Illinois limestone.

Slag and limestone are dumped into their respective bins at opposite ends of the raw-material building. When crushed to about 1½ inches in size, the limestone is dried in rotary driers, and is given a preliminary grinding before delivery to hoppers above automatic, electrically operated scales. Slag is fed direct to the drier, then pulverized and elevated to hoppers above the automatic scales.

At the scales the slag and limestone are proportioned to assure a uniform mixture, which is then ground in tube mills and elevated to hoppers above the rotary kilns. In these kilns the mixture attains a temperature of about 2500 degrees Fahrenheit and burns to a hard "clinker."

After curing for about ten days the clinker is reduced to about ½ inch size, and then is pulverized to pass a slanting screen with ⅛ inch openings. Gypsum is automatically added to regulate and retard the setting. Other tube mills comlete the grinding and deliver the cement to an inclined belt, which conveys it to the storage bins. On the conveyor the cement is automatically sampled every eight seconds. Every hour the accumulated sample is carried to the laboratories, where tests and analysis are made to assure uniformity.

From the storage bins the cement is drawn, weighed, sacked and trucked to the cars. (From the Guide Book of the American Institute of Mining and Metallurgical Engineers.)

The capacity of the plant is 100,000 sacks per twenty-four hours.. The analyses of the raw materials and finished product is given below:

ANALYSIS OF RAW MATERIALS AND PRODUCT

| | Slag. | Limestone. | Gypsum. | Cement. |
|---|---|---|---|---|
| Silica ($SiO_2$) | 34.48 | 2.22 | 2.06 | 19.61 |
| Alumina ($Al_2O_3$) | 12.99 | 1.27 | .40 | 7.71 |
| Ferric oxide ($Fe_2O_3$) | .99 | 1.07 | .40 | 2.22 |
| Iron (Fe) | 1.20 | .... | .... | .... |
| Calcium oxide (CaO) | 42.78 | 52.58 | 32.17 | 64.23 |

| | | | | |
|---|---|---|---|---|
| Calcium sulphide (CaS) | 2.90 | .... | .... | .... |
| Magnesia (MgO) | 3.28 | .78 | .... | 2.29 |
| Manganese oxide ($MnO_2$) | 1.38 | .... | .... | .71 |
| Carbon dioxide ($CO_2$) | .... | 42.08 | .... | .... |
| Sulphur trioxide ($SO_3$) | .... | .... | 44.25 | 1.73 |
| Moisture ($H_2O$) | .... | .... | .... | .... |
| Volatile matter | .... | .... | 20.72 | 1.50 |

*Wabash Portland Cement Company.* The plant of this company is located at Stroh, in Lagrange County. The plant is located between Big and Little Turkey lakes and uses the marl from the lakes and glacial clays for its raw materials. The composition of the raw materials and the products as given by the company are as follows.

| | Marl | Clay | Cement. |
|---|---|---|---|
| Lima (CaO) | 50.20 | 11.24 | 62.86 |
| Magnesia (MgO) | .45 | 3.60 | 2.34 |
| Alumina ($Al_2O_3$) | .... | .... | 6.58 |
| Ferric oxide ($Fe_2O_3$) | 1.20 | 17.12 | 2.14 |
| Silica ($SiO_2$) | 1.24 | 52.98 | 23.01 |
| Loss on ignition | 46.12 | 14.16 | .40 |
| Sulphur trioxide ($SO_3$) | .... | .... | 1.30 |

The annual production is from 300,000 to 350,000 barrels of cement.

With the exception of the chemical laboratory and office, the whole plant is under one roof. It is equipped with one steel rotary dryer, tube mill for coal grinding, clay pulverizer, four continuous rotary kilns, size 5x60 feet, daily capacity 480 barrels, three pug mills, three tube mills and four ball mills.

The marl is quarried by dredging with a clam shell bucket, loaded directly into narrow gauge cars for haulage to the mill. The clay is loaded with steam shovel into standard guage cars and unloaded directly into the plant. These raw materials are washed to remove deleterious matter from clay and marl. Mixed in the proper proportions the raw materials are ground in tube mills, burned in the kilns and the clinker ground into the finished product.

FINANCIAL STATEMENT OF THE DIVISION OF GEOLOGY

| OFFICE EXPENSES | October | November | December | January | February | March |
|---|---|---|---|---|---|---|
| Salaries | $308 33 | $308 33 | $308 34 | $308 33 | $308 33 | $308 34 |
| Traveling Expenses | 22 64 | 18 40 | ........... | 92 35 | ........... | 18 79 |
| Museum Specimens | ........... | ........... | 17 50 | ........... | 9 50 | 17 54 |
| Postage | 25 00 | ........... | ........... | ........... | ........... | 25 00 |
| Miscellaneous | 1 00 | 34 60 | 2 20 | 4 05 | 4 60 | 9 87 |
| Printing and Engraving | ........... | 363 76 | ........... | ........... | ........... | 34 22 |
| FIELD EXPENSES | | | | | | |
| Salaries | $338 33 | $30 00 | $30 00 | $30 00 | $60 00 | $30 00 |
| Board and Expenses | 31 10 | 48 65 | ........... | ........... | ........... | ........... |
| Total | $1,226 43 | $803 74 | $358 04 | $404 73 | $382 43 | $443 76 |

FINANCIAL STATEMENT OF THE DIVISION OF GEOLOGY—Continued.

| OFFICE EXPENSES | April | May | June | July | August | September |
|---|---|---|---|---|---|---|
| Salaries | $333 34 | $333 34 | $385 93 | $333 34 | $333 34 | $333 32 |
| Traveling Expenses | 29 12 | 22 88 | 11 05 | 16 59 | 23 96 | 12 99 |
| Postage | 50 00 | ........ | ........ | ........ | ........ | ........ |
| Miscellaneous | 1 00 | 12 11 | ........ | 25 35 | 3 00 | 1 50 |
| Museum Work | ........ | ........ | ........ | 260 75 | ........ | ........ |
| Printing and Engraving | 235 76 | 212 29 | 8 20 | 1,000 19 | ........ | ........ |
| FIELD EXPENSES | | | | | | |
| Salaries | 30 00 | 30 00 | 183 33 | 300 00 | 50 00 | 60 00 |
| Board and Expenses | ........ | ........ | 194 55<br>1,392 85 | 468 83 | 38 88 | 124 52 |
| Field Equipment | ........ | ........ | 464 35 | 54 00 | ........ | ........ |
| Total | $679 22 | $610 62 | $2,175 91 | $2,459 05 | $449 18 | $532 32 |

| | | |
|---|---|---|
| Total disbursements | | $10,525 00 |

*Receipts*

| | | |
|---|---|---|
| Gas fees collected in excess of deputy fees | $530 00 | |
| Geological reports | 64 58 | |
| On hand: | | |
| One Ford touring car | 425 00 | |
| One Ford truck | 928 50 | |
| | | $1,948 08 |

*Disbursements*

| | | |
|---|---|---|
| Salaries | $5,541 45 | |
| Wages | 32 70 | |
| Office equipment | 203 60 | |
| Postage | 145 00 | |
| Office supplies | 171 09 | |
| Field equipment and supplies | 150 86 | |
| Meals and lodging | 474 99 | |
| Railroad fare | 304 81 | |
| Ford car | 425 00 | |
| Motor expenses | 157 01 | |
| Telegraph and telephone | 124 66 | |
| Express, freight and drayage | 3 41 | |
| Auto, livery and boat | 198 52 | |
| State Fair exhibit | 75 | |
| Museum | 323 46 | |
| Printing of publications | 1,954 33 | |
| Topographic survey | 882 40 | |
| | | $11,094 04 |