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GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

PRELIMINARY REPORT

ON THE

BUILDING STONES,

CLAYS, LIMES, CEMENTS,

ROOFING, FLAGGING AND PAVING STONES,

OF

MINNESOTA.

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THE BUILDING STONES OF MINNESOTA.

INTRODUCTION.

HON. H. H. SIBLEY,

President of the Board of Regents, St. Paul, Minn.

DEAR SIR: I have received from Regent Chute, Recording Secretary of the Board of Regents, the resolution of the Chamber of Commerce of St. Paul, referred to me, as State Geologist, by the Board of Regents, with instructions to report to you as soon as possible on the economical value of building-stones, clays, &c., of the State—the enquiry to embrace material for building, paving sidewalks, cement, lime and brick.

In the regular course of the geological survey these important resources have come under examination wherever they have been seen in the counties examined. In the Annual Reports printed by the legislature are sundry statements regarding them, which, although of a preliminary character, yet have been intended to convey such information as could be given before the completion of the field work and the prosecution of more thorough investigations. Each county, when so surveyed and reported, has been supplied, through the county commissioners, with five hundred extra copies of the report pertaining to its own geology and economical resources. These should have been distributed, but sometimes they have not been, although they have been sent to the county court-houses. The following counties have been so reported, and their building-stones, clays, sands and limes have been briefly discussed, viz., Ramsey, Hennepin, Rice, Steele, Dodge, Olmsted, Houston, Fillmore, Mower, Freeborn. In a forthcoming report, now in the printer's hands, are similar accounts of the counties that border on the Minnesota River, while in the report for 1872 all the formations of the State are

reviewed with reference to their then known economical resources.

Lest, however, these reports fail to reach those most interested and immediately concerned, I will review systematically the building stones, clays, limes, &c., of the State, as a class, bringing together the most important facts relating to them, and giving some idea of their comparative value. This, however, will be only provisional, or introductory to a more full discussion of their merits, as compared with each other and with the same from other States, on the completion of chemical and physical tests now in progress, to be presented to the Board of Regents for the next legislature.

Building-stones—Granite.

More than a half of the State is underlain by that general class of rocks—the crystalline—to which granite belongs, and consequently the State has almost every variety of crystalline rock, whether in regard to the particular combination of the minerals that make them, their intimate structure and granular texture, or the size and color of the different crystalline grains. These rocks also consequently exhibit all degrees of durability and value for building purposes. The granites, however—by which term is meant here simply any granular, crystalline rock, without regard to the constituent minerals it may contain—are generally very durable; and whenever they are exposed above the canopy of drift can be wrought with profit, and with the most satisfactory results. While in the northern part of the State are large exposures of very fine light-colored granites, beyond the limits of settlement and roads, and particularly at Lake Saganaga, those in the valleys of the Mississippi and Minnesota rivers are of more special and immediate interest. These have been somewhat quarried, and their products—as building materials—can be seen in some of the principal buildings in various parts of the State. Not only so, but their products have been, and are now being, exported to cities outside the State. The gray granite that is quarried at Sauk Rapids, and which generally is seen in Stearns county, consists largely of quartz, embraced in a matrix of orthoclase, with but a small proportion of mica or chlorite. Hence it is hard, and very durable. The dark mica is biotite, and there is but occasionally a grain of hornblende. This last sometimes prevails largely over all the other minerals in small areas or veins, making a very dark-colored, and also generally a coarser-grained,

rock. There is also occasionally a grain of a triclinic feldspar and of magnetite, and some minute crystals of pyrite. These minerals have a relative hardness when expressed on a scale of ten, as follows; seven being the hardness of an ordinary knife-blade:

Quartz,	7.
Triclinic feldspar,	6 to 7.
Orthoclase,	6 to 6½.
Hornblende.	5 to 6.
Biotite,	2½ to 3.
Muscovite,	2 to 2½.
Chlorite,	1 to 2.

About one-half of the whole rock is made up of quartz, and two-thirds of the remainder of orthoclase. About one-half of the rest is triclinic feldspar, and the residue is divided between the other minerals, biotite predominating. It is plain to see that such an assemblage of minerals constitutes a very firm rock, and one that is rather hard to dress, but when once cut to form, and placed in a building will endure, practically, forever. The biotite, muscovite and chlorite, serve to make the granites easy to cut, and to quarry; and particularly when they lie in sheets or in indistinct belts through the rock, giving it a faintly striped aspect, constituting a gneiss, the rock can be got out easily in large, long slabs or blocks. When these are evenly scattered through the whole rock, the rock is simply softened, and in quarrying the fracture will have to be more completely guided by the plug and feather. For taking a polish, the absence of these soft minerals enhances the value of the rock. The durability of the Sauk Rapids granite has been tested at Washington, under direction of the Chief of Engineers, and was found capable of sustaining a crushing pressure of from 15,000 to 17,000 pounds per square inch.

The color of this granite, being a neutral gray, makes it suitable for a wide range of architecture; while the lighter, or more lively, tints of the Scotch and the Concord granites, render them less suitable for use in some structures. Such light-colored and reddish granites are found at Watab, a few miles north of Sauk Rapids, and also in a few places near St. Cloud and Rockville.

While the granites of Stearns county are massive, or non-gneissic, those of the Minnesota valley are almost invariably of a laminated structure, and of a reddish color. One of the principal exceptions to this statement consists in the large granite outcrop

near the foot of Big Stone Lake. The Minnesota valley granites differ from the St. Cloud granite also in being softer, on account of having less quartz, and more of the cleavable minerals, orthoclase and mica. They are also easier to quarry, but they have not been much worked yet. Some of the recent cuts in the red granite near Montevideo, by the grading for the railroad, show a very superior variety of rather coarse-grained, red granite, which cannot fail ultimately to be in great demand. The great stoneless tracts of prairie lying south and west of the upper Minnesota valley region will before many years make the granites there very valuable. They extend from near New Ulm to the foot of Big Stone Lake.

The so-called "granite" of Duluth belongs to a very different class of rocks, and is more properly styled *gabbro*, a new term derived from Italy, and applied to an igneous rock consisting of the triclinic feldspar, labradorite, augite, and a magnetic oxide of iron containing titanium. These minerals are all softer than quartz, which is wholly absent from the Duluth rock, but which makes up so large a part of the St. Cloud granite. It is strange, therefore, that the Duluth rock should have been so generally regarded as harder than real granite, and particularly as harder than the St. Cloud granite. The mineral augite, which makes up, generally, less than one-fourth of the whole, has a hardness from five to six, on the scale of ten, and labradorite is but little more. When this rock begins to decay the augite changes first, making a greenish soft mineral, like chlorite, and this change sometimes is found to have gone on to a great depth in the rock without any change being seen in the other minerals. In such cases, while the rock is not much injured for building purposes, it is more easily quarried and dressed. While taken in a mass, this Duluth rock may correctly be said to be softer than the St. Cloud granite, it is tough and firm, being perfectly crystalline and compact. The magnetite in this rock sometimes becomes so abundant that it spoils it for building, and even becomes an iron ore, and has attracted attention as such. The iron ore reported some years ago at Duluth, and that in Herman, a few miles west of Duluth, and that at Iron Lake, north of Grand Marais, is all of this variety, and in some cases it is pure and valuable; but it is damaged by the presence of the titanium. The Titanium is not so much a damage to the iron as an impediment in the reduction of the ore. At Duluth this rock has been used in some foundations, but the difficulty of dressing it, as well as of quarrying, has prevented its

acceptance as a general building material. Its strength is about 17 thousand pounds per square inch.

This rock is associated at Duluth with one of a very different sort, which has not attracted attention, and has not been quarried. In the hills back of Duluth it changes suddenly to a red granite, supposed to be derived from the fusion and metamorphism of the Fond du Lac red shales and sandstones when the igneous rock was poured out through them and over them. These two kinds of rock are closely intermixed in patches, sometimes of large area, and extend thus all the way to the northern boundary line of the State, the red rock showing various stages of metamorphism and crystalline condition. This red granite in some places is very coarse-grained, and beautiful, something like Scotch granite, and in other places it is very fine-grained and compact, as at Duluth. It contains quartz, generally in large quantity, red orthoclase, and green hornblende or chlorite, being more correctly a syenite than a granite.

There is a very firm, syenitic granite near Motley, on the Northern Pacific R. R,, which is similar in outward appearance to the St. Cloud granite, and will furnish stone for a large tract of stoneless country west of that point, this being the most westerly outcrop of rock known on the line of that railroad within the State.

The red quartzyte at New Ulm, which also is seen in Cottonwood, Watonwan, Rock and Pipestone counties, is sparingly used for a building stone at points contiguous; and one or two carloads are known to have been shipped to Minneapolis. It is the hardest stone in the State, or in the United States, probably, that can be stated to have been used for building. It consists almost wholly of quartz; the red color being due to iron oxide which is disseminated among the grains but does not enter them. As a layer embraced in this rock the material known as "pipestone," or catlinite, is found in Pipestone county and other places in southwestern Minnesota. This rock it is very difficult and costly to dress into dimension blocks, but it is indestructible when once placed in a wall.

Sandstones.

Next in ascending order, as building materials, come the sandstones, if we omit the black argillyte, or roofing slates and their associates, seen at Thomson, which will be treated under *Roofing Slate.* The red sandstones at Fond du Lac are probably the most

valuable deposit, taken on all accounts, that the State possesses as a building stone of that kind. They are of the same formation as the New Ulm quartzyte, but were less hardened at the time of their upheaval. They lie tilted toward the south or south-east. They are associated with, and overlie, a vast thickness of soft red shale which passes sometimes to a shaly, red conglomorate, the same that in other places about Lake Superior is in contact with the igneous rocks and becomes copper-bearing. This red sandstone is well known in Milwaukee, Chicago and Detroit. The quarries in it further east furnished the red sandrock used in the Milwaukee court-house; and a great many brown stone fronts in that city and in Chicago were obtained from it. It was formerly quarried on Isle Royale and sold in Detroit as *Isle Royale Brownstone.* While it consists almost entirely of quartz, the grains are not so firmly cemented, or united as to render it objectionably hard. Its grain, color, and texture vary slightly. On Isle Royale, when quarried, it is fine-grained and rather brittle, being more highly metamorphosed than at Fond du Lac. At some points it has a mottling of red and gray or even of green, as at Sault Ste. Marie, at the eastern end of Lake Superior, where the ship canal is cut in, and largely built of it. In some places it is so loosely cemented as to crumble, and to be rendered useless for building, and in others it contains pebbles, rounded quartz pebbles, of a nearly white color, or becomes wholly conglomeritic. At Fond du Lac some of all these features can be seen, but there is still at that place a great abundance of fine stone of the best quality. This great formation forms the southern rock-barrier of Lake Superior almost without interruption from Duluth to Sault Ste. Marie, but it is not always of so dark a color as it is at Fond du Lac. The famed "Pictured Rocks" of the south shore are formed of it, and the Apostle Islands are caused by remnants of it that withstood the erosion of the glacial forces. Its strength as tested at Washington, proved to be from four to five thousand pounds per square inch. Several business blocks have been made from it in Duluth, and the new Westminster church at Minneapolis is being constructed of it. This formation is seen not only at Fond du Lac, but (probably) at Pokegama Falls, on the Upper Mississippi, and in the base of the bluffs at Winona, but the most favorable and promising points for quarying it are at Fond du Lac.

The freestone at Hinckley is probably not of the same formation, but pertains to a higher horizon. It is exposed on the banks of the stream passing through the village, and at points further

down. As a building stone it is considerably lighter colored or more nearly that of the Kasota stone, and more easily wrought than the Fond du Lac stone. It is in even, heavy beds, and can be easily got out. It is as firm, and as desirable for all purposes of architecture to which it is adapted, as the Cleveland freestone which is so largely used. It can be dressed more cheaply than the Fond du Lac stone, and can be cut into ornamental forms for capping or for columns. Its compressive strength, which has not been tested yet, is doubtless very nearly the same as that of the Ohio freestone. It has lately been put into the foundations for the high bridges and trestle-work of the St. Paul and Duluth R. R. along the dalles of the St. Louis river. It is the only rock known between White Bear Lake and the slate region of Thomson, which begins near Goose Lake station.

The other sandstones of nearly the same geological horizon are not very good for building, being too friable. They are exposed in the bluffs of the Upper Mississippi below Hastings, and of the St. Croix below and above Taylor's Falls, where they have been put into one or two business blocks. They are of rather coarse grain and friable on first quarrying, but the weather operates to harden them somewhat in the coarse of a few months. When they are finer, and mingled with an aluminous sediment, they are also somewhat magnesian. They are then fit for rough walls, but for first-class architecture they cannot be used, owing to the thinness of the layers and the general incoherency of the grain. Still in some towns this kind of stone is employed exclusively for the general home demand, as at Hokah and Lake City.

The Jordan sandstone, in the Lower Minnesota Valley, is very much like that at Taylor's Falls, but is in a much higher geological horizon. It has been used considerably at Jordan, and serves a good purpose for general building; but it cannot be recommended for first-class structures. It is of a light color, but stained and clouded, or striped, by a yellowish or rusty iron cement. It is likely that the darker-colored beds of this stone will be found most durable. This rock appears in the Minnesota valley, forming islands and rapids near Carver. If it were to be wrought along the Minnesota river, where it has been for a long time subject to the rusting and cementing action of the waters of the river at periods of flood, it would be found much harder and valuable.

This is the case with the St. Peter sandstone above Fort Snelling. Ordinarily this formation is very friable, and particu-

larly where it is freshly exposed or is being continually reduced by the action of winds or by running water. But when the river water occasionally or periodically overflows it, the repeated evaporation of the water leaves a deposit of iron-rust, which on entering among the loose grains of the rock soon so firmly cements them, especially on being thoroughly dried, as to make a useful building stone. Such a process goes on in all low grounds where water evaporates without free escape, and generally causes a rustiness on the mud or on the dead twigs or roots of the place, or even goes so far as to form a bog-iron ore. If a rock be exposed there it becomes more or less rusted, and if before incoherent it becomes firm. Although this stone has been put into the piers of the bridges at Fort Snelling in large blocks, it can hardly be said to constitute a reliable supply of good stone for the cities of St. Paul and Minneapolis. When evenly and thoroughly cemented by the iron-rust it will form a durable rock, but its liability to inequalities in the hardness of the mass, to variations of color and to the exhaustion of the supply, will operate against its extensive use.

The stone used at and below Austin, taken from the low banks of the Cedar river, seems to belong to the upper Devonian. It is believed to lie conformably over the Devonian limestones that are seen in outcrop further down the river a few miles south of the State line in Iowa. The stone itself in its natural color is of a light blue color, and that color shows on most of the quarried blocks about the heart of the bedding; and on deep quarrying it would doubtless show only a blue color. Yet the stone as now used is very generally of a buff color to the depth of half an inch to three inches, depending on the amount of weathering and oxydation. The thinner beds are altogether changed to that color. The texture of the stone is close, and the grain is homogeneous. Some large slabs and blocks are sawn for bases to tombstones, and worked down to a very smooth surface. It is more safely sawn to any desired dimension than cut or broken, yet it is not in the least crystalline. Its aspect at a distance is that of a fine-grained sandstone, yet it contains no apparent grit. It is so soft that it can be cut without difficulty, appearing much like an unusually indurated blue shale, but it hardens in use and serves a useful purpose in common buildings, but cannot be depended on for first-class structures. Its argillaceous composition will ultimately cause it to crumble, especially if it be subjected to frequent changes of moisture and dryness.

At several points in the banks of the Minnesota river between

New Ulm and Mankato a hard, siliceous sandstone is exposed, which has supplied some very good building material. The layers are about four inches in thickness, and are tough and firm. They are associated with alternating layers of a friable sandstone, which aids in their extraction. These beds are sometimes so coarse as to justify their being designated as conglomeritic. The stone is very durable as a building material, but the toughness and hardness of the texture, and the thinness of the beds, make it more suitable for flagging than for building. It is typically exposed on the land of William Fritz, Sec. 16, T. 109, R. 29, in Nicollet county, and other places near.

Limestones.

The lowest limestones in the geological scale are those seen in the bluffs of the Mississippi river, and in the St. Croix valley. They generally form the tops of the bluffs, and cause the precipitous portions, the sloping talus being taken up with one or more of the sandstones above mentioned. These limestone beds present a varied lithology, and cause some very interesting topographical features. As a building stone they are wrought at all points where there is a demand (except Lake City) between Stillwater and Winona, along the Mississippi valley on the Minnesota side, and also at several places further west, as at Caledonia in Houston county, Lanesboro and Rushford in Fillmore county, and at points in Winona county. The material they supply is, in general, a magnesian limestone, of a light buff color, firm, but sometimes a vesicular or porous texture, and often having a considerable proportion of quartz. An analysis of a sample from Sugar Loaf, Winona, gave the following result:

Insoluble (mainly quartz,)	24.21
Ferric and aluminic oxides,	3.32
Calcium sulphate,	4.32
Calcium carbonate,	47.11
Magnesium carbonate,	20.67
Total,	99.72

showing that nearly one-fourth of the whole consists of quartz. In other places would be found less quartz. And this is particularly the case at Frontenac where the rock is so even-grained, and so free from quartz, that it is sawed by machinery into such slabs or blocks as are wanted. The quarries at Winona and Red Wing are in beds of this stone that are quite similar as to texture, being

open and loose, or having small scattered cavities. In these cavities are sometimes linings of drusy quartz crystals. In other beds this quartz is gathered instead into nodules of chert or flint, which although having a white exterior are hard and often gray within. This is the condition of the quartz in the stone at Frontenac, but these flint lumps are not common there. In other places whole beds are cherty, and worthless for a building-stone. This formation, which probably at the present time furnishes more stone than any other in the State of Minnesota, is destined to be still further used for the same purpose, as it contains a vast amount, is most favorably situated, at its exposures, both for excavation and for shipment and transportation, and supplies one of the best materials for all purposes of architecture. It varies from a light buff color to a light drab. When placed in a structure it has a lively and cheerful expression. At Frontenac it is cut into ornamental forms with comparative ease, and the same kind of beds as those at Frontenac are found throughout the southeastern part of Goodhue county, and the northern portion, at least, of Wabasha. It is but slightly changed after many years exposure to atmospheric influences, indeed it has not been in use long enough yet in the State to show any change whatever by lapse of time, although it is in some of the oldest buildings of the State. The homogeneity of its composition and texture, as at Frontenac, and the regularity and thickness of its bedding, are qualities that enable it to supply slabs and blocks of any desired dimensions. Its resistance to pressure, amounting to five to seven thousand pounds per square inch, is sufficient to warrant its use in all ordinary structures, while for door moldings and caps, for sills and water-tables, and for all trimmings to brick structures it is unsurpassed.

That limestone formation which is wrought at Mankato, Ottawa, Kasota, Shakopee, and St. Peter, lies about 100 feet higher in the geological scale than the last mentioned, but it is in nearly all places where wrought of nearly the same character, and as useful for all purposes, though it does not present the evenness of texture and freedom from quartz seen in the Frontinac stone. At Kasota the river has at some early time stained it, in the same way that it has the St. Peter sandstone above Fort Snelling, giving it a rusty pink color, or a *fawn* color, as described by Featherstonhaugh, and at the same time greater tenacity and endurance under pressure—ten thousand pounds per square inch. For its beauty, its regularity of bedding, which is sometimes nearly two

feet in thickness, and its homogeneous texture, which renders it easy to shape into all forms, it is adapted to ornamental work as well as heavy masonry. It is cut, as at Mankato, into posts, sills, caps, and water-tables. For its adaptability to all uses it is worthy of being ranked with the Waverly sandstone, which is beginning to be imported into Minneapolis and St. Paul from Ohio, and it is more enduring even than that, under the action of atmospheric changes, owing to the more general and abundant dissemination of the calcareous cement; while its variegated coloring and its more lively expression make it preferable in many kinds of work. It is used in the State Lunatic Asylum at St. Peter. The Episcopal church and the old Asylum building are also constructed from it. The Baptist church in St. Paul is built of the Kasota stone. In old structures where it has been exposed for a number of years to the disintegrating action of the elements it shows as hard and sound as ever. It even becomes harder at first on exposure, as the quarry water dries out.

The Trenton limestone, which is largely used at Minneapolis, St. Paul, Northfield, Faribault and Chatfield, and was formerly quarried at Fountain for shipment to points further west on the Southern Minnesota R. R., is a bluish, rather dark-colored stone, that varies in value very much in going from place to place between Minneapolis and the southern part of the State. At points toward the north, nearer the old shore line of the palæozoic ocean, much aluminous shale was deposited, even in those comparatively quiet times when marine animals flourished and on their death supplied a considerable calcareous sediment. Further south the quiet, lime-producing epochs were less mixed with aluminous sediment, and were separated more distinctly by periods of agitation when large amounts of shale were deposited. Hence in this formation at Minneapolis and St. Paul the aluminous shaly ingredient is distributed through the calcareous, and also constitutes heavy beds of itself; while at Northfield the calcareous layers are pure, and at Fountain are almost free from alumina and sand; and at the same time in passing toward the south the purely aluminous beds become less and less as the calcareous become more and more. This is unfortunate for the cities of Minneapolis and St. Paul, which have to depend very largely on the Trenton limestone for building material or to import from other places. The stone itself has an attractive and substantial aspect, when dressed under the hammer the variegations due to the alternating shaly and limy parts giving the face a clouded appearance as of gray marble, without being

susceptible of a uniform polish. Where protected from the weather the shale will endure and act as a strong filling for the frame-work of calcareous matter for a long time; but under the vicissitudes of moisture and dryness, and of freezing and thawing, it begins to crumble out in a few years. This result is visible in some of the older buildings, both in St. Paul and Minneapolis, and has provoked a very general inquiry for some suitable substitute in those cities. The natural color of the stone, on deep quarrying, is blue, but it is often faded to an ashen drab to the depth of several feet, depending on the ease with which water and air find access within. The porous layers are apt to be most faded. The long-weathered surface is of a light-buff color, or if iron be present in dripping water or contained in the stone as pyrites, so situated as to be oxydized, the color is sensibly deepened to a rusty yellow, and at the same time the stone is rendered more enduring on account of the irony cement. This is noticeable at Minneapolis and St. Paul, where the old river bluffs, formed before the last glacial epoch, have endured the exposure of a much longer period than the river bluffs between Fort Snelling and Minneapolis that have been formed by the recession of the Falls since the last glaciation. The shaly portions in particular, where closely mingled with the calcareous, are so stained and hardened that the rock seems almost another formation. It becomes separated into layers of two or three inches. Some of the first large buildings erected in St. Paul were made largely or wholly from such iron-stained and weathered parts of this formation, and, although they do not present that uniformity of color and appearance of solidity and strength that the dark blue stone lately quarried gives to a building, the stone itself has withstood the climate and storms of this latitude more successfully than later buildings constructed wholly of the blue stone. Toward the southern portion of the State this changed condition is not so noticeable, indeed is not so possible. The beds are more compact and calcareous, and the effect of the elements is more superficial. Hence, while this formation as a building material at its northern outcrops at St. Paul and Minneapolis is rather inferior, at its southern exposures it furnishes a dark-blue stone of excellent quality. Nothing can be more suitable for heavy walls, and especially for foundations below the water-table, and for all Gothic structures, than the blue limestone taken from it at Fountain, or at some of the quarries at Faribault. The beds themselves are sometimes a foot thick, but are more generally from six to eight

inches. On deep quarrying they combine into heavier layers. It will be necessary to add to this account the statement that at Minneapolis, and to some extent also at St. Paul, there is a very different sort of stone in the Trenton limestone formation overlying the beds that are wrought, which is more enduring than the regular building-stone. This does not appear in the quarries near the Falls, but is seen in the quarries near the University, where the formation has not been so much eroded. This rock is generally rejected by builders, and is confounded with the worthless shale that separates it from the regular building-stone layers. It is an impure limestone, containing a large per cent. of silica and alumina, and also of carbonate of magnesia. It is more correctly a *dolomite*, resembling in that respect the rock at Red Wing and Winona, though not having the bright, cheerful color of those quarries. It is sub-crystalline, rough to the touch, hard, but splitting to thin lenticular chips under the weather. It is of a blue color within, but on exposed surfaces becomes a dirty buff. The grain is close, except for the cavities resulting from absorbed fossils. The fragments into which the stone weathers out are brittle and somewhat sonorous under the hammer. The older portion of the State University contains a large amount of this stone, and its greater durability than that of the regular building-stone can there be seen. This part of the Trenton limestone is about eight or nine feet thick, and it is separated from the blue stone usually wrought by a thickness of five or six feet of worthless shaly rock, which builders sometimes smuggle into a wall. It would be well if this stone were more generally used. The Faribault marble is a layer in the regular building-stone beds.

Still higher in the geological scale are limestones that appear in the southern counties, known as Upper Trenton and Galena. The banks of the streams that pass into Root river in the western part of Fillmore county, and in southwestern Olmsted exhibit many large exposures of the Upper Trenton, and there are many quarries in it, but they are mainly for quicklime. They might be utilized for building-stone, since the rock is heavy, firm, free from shale and sand, and easily accessible. The Galena beds are extensively wrought at Mantorville and at Spring Valley, and somewhat at other points in Fillmore and Olmsted counties, and in northwestern Goodhue county. The color of this rock is buff, sometimes dark-buff, although on deep quarrying the heart of the beds shows that its normal color, like most other limestones, is blue. Its composition, like that of the rock at Red Wing and

Winona is dolomitic, comprising a large percentage of carbonate of magnesia, but it is without the quartz that is found in the limestones along the Mississippi, and is on that account less hard to quarry and cut, as well as less durable. Its texture is open, even porous, with minute cavities, and sometimes with larger openings due to the absorption of fossils. In this latter case it presents a rough and forbidding aspect. This, however, is not common, the sedimentation having been generally so undisturbed by chemical or mechanical agencies that the layers are yet well preserved. The grain is crystalline, and sometime granular. Minute crystals of brown spar often line the cavities. It sometimes also embraces iron pyrites which, weathering out, stains the face of the rock with iron rust. The granular texture seen in some parts of this formation, which is a character seen in most magnesian limestones, has sometimes made it pass for a sandstone. As a material for building it is a little surprising that this formation has not been more employed. It occurs in fine exposure in the southeastern part of Goodhue county, abundantly in Dodge county, as well as in Olmsted and Fillmore, along the streams, and can be extensively wrought. It not only furnishes a building material suitable for all ordinary uses in foundations and abutments for bridges, but it also cuts easily to a regular and smooth surface. Its bedding is sometimes heavy, reaching two or three feet in thickness, and the stone is strong enough to endure both pressure and long weathering. It is of a light and lively color, and in that respect has the advantage of darker-colored stone.

The Devonian limestones are of two very different sorts. One sort is found in Fillmore county, southwest of Spring Valley, and particularly along the tributaries of the upper Iowa river. This stone in all respects except its more even and close texture, being without the porous features, is like the Galena limestone last mentioned. Its color is the same, but its even and non-vesicular texture is enough to distinguish it from that at a glance. The bedding is also less thick, being, when in exposure, usually less than eight inches, though when quarried it is also in heavy beds. It is a yellowish, magnesian limestone, sometimes with a finely arenaceous composition, and is suitable for most purposes in common masonry. It is tolerably free from calcite lumps, but has some chert nodules. It is, however, generally useful for a cut-stone in its outcrops in Fillmore county. It has been but little opened in Minnesota, principally because the region in which it

occurs has not yet developed so as to create a demand for first-class stone for building. In Michigan and Ohio this formation supplies some of the most valuable limestone for building.

The other sort of Devonian limestone overlies the last, and is much finer grained. It is light colored, or sometimes nearly white, hard and fine. It is uniform in grain and texture, and not in the least porous. Some parts of it would make a beautiful white, or nearly white, marble, if it were deeply quarried. In ordinary working it breaks with a conchoidal surface, but by some care a uniform cutting can be made in any direction. Some of the beds of this rock are about ten inches or a foot thick, but they are more frequently about four inches, or six inches, and can then be got out in slabs of considerable size. It is a fortunate circumstance that sometimes layers of clay are interposed between the beds, which facilitates their being obtained in sizable blocks. The most favorable point for quarrying this stone is at Le Roy, in the southeastern part of Mower county.

Limestone suitable for all purposes of building is found well exposed for quarrying along Deer creek, at Frankford, in Mower county. The age of this rock is not fully established, but is supposed to be of the Upper Silurian age. This stone is suitable for heavy masonry, being often three feet thick or more. The stone has about the same color as that at Le Roy, but is somewhat darker. Its texture is vesicular, with abundant calcite, and some chert. It is apparently a magnesian limestone.

Roofing Slate.

At Thomson, where the St. Paul and Duluth R. R. crosses the St. Louis river, the Huronian slates have been opened for the production of roofing slate, and with very good success. This enterprise is not now carried on, but there is no known reason why it should not be revived and made profitable. The slate is black, hard and compact, apparently being of the best quality. Considerable quantities which were taken out over ten years ago have been exposed on the ground to the weather at that place, and show no effect from such severe tests. The amount of the supply here is exhaustless, but of course some care must be exercised in selecting the beds for quarrying. Different grades of hardness can be obtained, which will supply material not only for roofing, but for writing slates, tables, mantles and all other uses to which such slate has been applied. These slate ridges being the most western known in the United States over a great tract of habita-

ble prairie, and also the nearest to a large portion of the central and southwestern States, are sure to be largely used when they are sufficiently known, and when the growth of western cities has reached that stage when slate is in constant demand. They are perfectly accessible from the south by the St. Paul and Duluth Railroad, and from the west by the Northern Pacific Railroad.

Paving Stone.

For pavement, in ordinary roads, or in the streets of cities, a variety of material has been used, but in general the harder and tougher kinds of rock are the best. Sandstone is altogether too soft, unless it has been hardened into a quartzyte by some method of metamorphism. Such changed sandstone is the quartzyte at New Ulm and southwestward to Rock county, and also the quartzyte or cemented sandrock of the Cretaceous, below New Ulm, in which the cement being principally silica, has compacted the entire mass so as to form one very tough substance. This latter, however, is not obtainable probably in very large quantities, and its cemented condition is variable and perhaps not extensive. Still whatever there might prove to be, would, especially in connection with the Potsdam quartzytes of New Ulm and Rock and Pipestone counties, furnish a supply ample for that part of the State for hundreds of years, and for a large export to adjoining parts of Iowa and Dakota. The limestones of the Lower Magnesian, viz., those at Winona, Red Wing, Mankato, Kasota and Shakopee, are better for paving material than other limestones that contain less silica, being firmer and harder, and less soluble by water. Many important roads are macadamized in the United States with ordinary limestone, broken into angular pieces of a size that will allow them to pass readily through a ring 2½ inches in diameter. In general, however, this paving is apt to be very dusty in the summer, and muddy in the wet seasons, owing to the combined action of water which softens or dissolves the stone, and the pulverizing effect of travel. Hence, they soon wear out and need repair. Of course the difficulties are remedied, almost wholly, by using a material that is unacted on by water and is able to resist crushing under ordinary travel. Of such material Minnesota has a superabundance. The granites, greenstones, traps and quartzytes, are the most conspicuous feature in the geology of the northern and eastern portion of the State. The so-called trap-rock at Taylor's Falls is the most accessible of the firmer kinds of stone, excepting the pebbles and boulders

found in the drift scattered nearly all over the State. The granite at St. Cloud and Sauk Rapids is also accessible, and is nearly as durable. The gneisses of the Minnesota valley are very suitable for the same use, and the rocks of the north shore, being very largely tough dolerytes, are superior for this purpose. Some of the best exposures are at Duluth, known as *Duluth Granite.* These dolerytes of the north shore are wrought into rounded forms on the beach by the action of the waves, and sometimes these rounded stones alone constitute the beach. They have been carried by ship-loads from Minnesota to Chicago and other cities for use in paving streets. They are found in considerable numbers in grading the streets of Minneapolis and St. Paul, associated with similar forms of other hard rock, and should be preserved for paving, by order of the city governments, but they are thrown with the dump and buried again. A little thoughtfulness would save thousands of dollars to each city. The Telfourd pavement consists of a sub-pavement, or artificial foundation, covered with angular pieces of broken stone; that of Macadam rejects the sub-pavement, and lays the angular pieces of broken rock on any natural surface. Telfourd's sub-pavement consists of stones varying in depth from nine inches at the center of the road to three inches at the sides, set with their broadest edge downward, and no stone being more than four inches broad upon its upper edge. Over this as a foundation were spread broken stones to the thickness of three or four inches, but not exceeding six. The Hughes pavement has a concrete of gravel and lime for a foundation.

Flagging.

So far as known the State is not abundantly supplied with material suitable for flagging—that is, with stone that naturally and easily is separable into sheets for flagging. Yet it is to be borne in mind that there has not yet been created a large demand for flagstones, and that perhaps when the demand arises some of the quarries now in operation, or others, will be found to possess a good supply of flagstones. Some of the beds most likely to furnish such stone of a durable character, are the lighter colored, or at least the thinner bedded, portions of the red quartzyte at New Ulm, or at some other points southwest of them. In the exposure of this quartzyte at Redstone, near New Ulm, some of the lower layers are argillaceous and thin, and can be got in large slabs, which, with proper handling, could be broken to shape and size for

flagging; but in general such beds are covered by a large thickness of firm, heavy layers of quartzyte. The Cretaceous beds at Fritz's quarry, a few miles below New Ulm, and at other places near, also will furnish a pretty good flagging. It would be much easier to obtain than the stone at Redstone, the beds being separated by other layers of incoherent sandrock. There are places in the Minnesota Valley, above New Ulm, where the quarries would also furnish a good flagging stone, but, of course, while more enduring in use, this stone would be more difficult to quarry. Of the limestones, or siliceous limestones, the beds of the St. Lawrence or Shakopee formations are most promising. The former is in outcrop, as already stated, all along the Mississippi river from Winona to Hastings, and thence up the St. Croix valley to and beyond Stillwater, and the latter is characteristically exposed at Shakopee, Ottawa, Kasota and Mankato. Some of the thinner beds will make a very superior flagstone, and are now somewhat used for that purpose. At the present time they are generally broken up for lime-burning or are sold as interior building stone. The exposure of the St. Lawrence at Hebron and other places in Nicollet county, and at St. Lawrence, nearly opposite Jordan, in the Minnesota valley, are also very favorably situated for obtaining flagging. At St. Lawrence, particularly, the beds are of about the right thickness. Some firm slabs of flagstone are obtained at Kasota.

In the northern part of the State nothing is known that will answer for flagging unless it be certain layers in the red sandrock at Fond du Lac, or the argillyte at Thomson. The former would be easily tested, and can be easily obtained. It would be rather soft for such use. The former can be got in large slabs, but it would be refractory to work into shape, and slippery in use, though very firm and durable when once laid.

Cement.

Nothing is known in the State that will produce hydraulic cement, unless it be the bituminous shale that is found in the Trenton in Rice and Goodhue counties. This, however, is so small in amount, being but few inches in thickness, that it will never be used for that purpose. It is found in the Rice creek quarries in southeastern part of Rice county, and in the quarries at the Oxford Mills, in Goodhue county, and is closely associated with the upper part of the Trenton layers. It has so much combustible material that it will burn from a common match, with a

flame. The same layers doubtless extend through the southern part of the State, since they are also found at Dubuque, in Iowa. (See the Report of the survey for 1879.)

Lime.

Four different sorts of limestone are found in the State suitable for lime-burning, and two only are used. They are as follows:

1. The Silico-Magnesian Limestone, of the Low. Magnesian.
2. The Limestone of the Trenton formation.
3. The Magnesian Limestone of the Galenia formation.
4. The Magnesian Limestone of the Upper Devonian formation.

Of these, the first two only are calcined to any notable extent, although there are isolated kilns that supply a local demand run on the other formations.

1. The Lower Magnesian Formation, as here referred to, embraces the Shakopee and the St. Lawrence formations, and any geologist will understand at once where to look for lime from that rock. It has already been said that the limestone exposures along the Minnesota valley are in the Shakopee formation, except those at St. Lawrence, Jessenland and Hebron. It will also be necessary to except the Cretaceous Niobrara near New Ulm. Lime from the Shakopee is made extensively at Mankato, Ottawa, Shakopee, and somewhat at several intermediate points, and at Northfield. It is generally of a very dark color. It is distinguished in some places as "black lime" in comparison with that burned from calcareous tufa which is then called "white lime." In other places it is known as "leather-colored" lime. Yet even when the bulk of the lime produced is of a dark color, some inconsiderable spots and streaks are almost as white as lime made from any other formation. The lime made at Shakopee, Scott county, largely used at St. Paul and Minneapolis, is exceedingly dark, and is commonly known as "leather colored." It has not the purplish or ashy tint of some dark Ohio limes, from the Hamilton limestone, but an ochreous, or umber-color. It is also specked and sometimes streaked with whitish spots, or with shades of light brown, and in slacking it takes the color of rich cream.

The composition of the rock furnishing this lime shows that it is really a *dolomite* instead of a limestone, having a per cent. of carbonate of magnesia varying from 25 to 40. It also has generally an insoluble portion varying from 15 to 24 per cent., though of course there are a few layers in the formation that consist almost

entirely of sand and are unfit for lime, while also some portions have a very small amount of insoluble substance. One of the purest dolomitic samples of this formation has been obtained at Clapp's quarry, a short distance below Mankato, and the lime made from it is of superior quality. An analysis of this by the survey gave the following result:

1. Insoluble portion,	2.82
2. Ferric and aluminic oxides,	1.39
3. Calcium sulphate,	6.74
4. Calcium carbonate,	52.22
5. Magnesium carbonate,	36.04
Total	99.21

An analysis of a fair average sample of the limestone burned at Shakopee gave the following results:

1. Insoluble portion,	16.22
2. Ferric and aluminic oxides	1.14
3. Calcium sulphate,	73
4. Calcium carbonate,	54.28
5. Magnesium carbonate,	27.48
	99.85

In the foregoing, Nos. 1 and 2 are detrimental to the product of the kiln. No. 2 is converted to calcium oxide in calcining, and should be counted as lime, while the remainder, Nos. 4 and 5, are both valuable ingredients in the calcined product. The insoluble portion consists almost wholly of sand, and while it gives weight and bulk to the lime, it is an incumbrance to the consumer.

The same formation at Kasota, where worked for building stone, on analysis, gave the following result:

1. Insoluble matter,	13.85
2. Soluble silica, Al. and Fer. oxides,	1.49
3. Calcium carbonate,	47.904
4. Magnesium carbonate,	35.227
5. Sulphuric oxide,	trace.
6. Water and alkalies, undetermined,	1.529
	100.000

The rock at Ottawa and at Mankato has substantially the same composition, but can be made to vary in the selection of the samples. At Mankato great care is taken to select for lime certain layers only that are free, or nearly so, from the detrimental ingredients, and which furnish a lighter-colored lime, with less sediment unslacked.

The quicklime made from the St. Lawrence formation along the Mississippi river, and especially at Red Wing, while perhaps of a somewhat lighter color than the Shakopee lime, does not differ from it in any essential points. The rock, on analysis, is found to be very nearly the same, and it has very nearly the same outward characters. The stone that is cut largely at Frontenac is one of the best for making lime. It is uniformly porous, and is found to have much less silica. This industry could advantageously be carried on in connection with stone-cutting at quarries that furnish the Frontenac stone. The stone would calcine evenly and easily.

The lime that is made from magnesian limestones, or dolomites, differs from pure lime both in composition and in its action when used. It was formerly supposed that the presence of a considerable per cent. of magnesia was detrimental to lime, and it used to be the aim of lime-burners to avoid such stones and seek for the pure limestones, or those that contained about 90 per cent. of carbonate of lime. But it has been found that the presence of the magnesia, while probably actually reducing the quickly cementing quality of the lime, yet gives it that moderateness of slacking and setting which really makes it more useful in the hands of masons, and also prevents the waste and loss that arises from the immediate setting of the pure limes. The magnesian limestones burn easier, the presence of the magnesia acting to disseminate the heat more perfectly through the whole than can be done with pure calcitic limestones, and also in some way apparently causing a granular, and often a vesicular, texture to pervade them, which allows the penetration of the heat within and the quick expulsion of the carbonic acid. As they burn more easily, so they slack more slowly, and with less heat evolved. They set more slowly also. This last quality is what makes them more useful than the pure limes. With a single spreading of mortar several bricks can be laid before the lime sets, but with pure lime but two or three bricks can be laid. This quality is especially desirable in plastering when some time is required in rubbing and smoothing the surface.

2. The limestones of the Trenton Formation are found at Minneapolis, St. Paul, Faribault, Lime City (near Spring Valley,) and at many places in Olmsted and Fillmore counties. The lime made from this rock is more nearly a pure lime. Its chief impurities are alumina, or clay, and iron. It is true, also, that there is a bed within the Trenton at Minneapolis that seems to be dolomitic. It is the uppermost part of the quarries in the bank of the river below and opposite the University, and is generally rejected by the quarrymen, In the weather it becomes thin-bedded, and has a dirty buff color, but on deep quarrying it becomes thick bedded. It is highly probable that a very good quick-lime could be made from it. It has never been used for lime. It shades imperceptibly into the impure calcareous shale below it, which separates it from the regular building stone, and care would be necessary to avoid those layers. With this exception the Trenton formation will furnish, so far as known, only a pure, or nearly pure lime, which will slack quickly and with the escape of a considerable heat, and will set quickly and firmly on being exposed. A large amount of lime is made from the Trenton formation at Lime City, and shipped at Spring Valley to points west on the Southern Minnesota R. R. Analyses of this rock have been made by the Survey with the following results:

	Portion Insoluble.	Water.	Ferric Oxide, Alumina, Ferric Phosphate.	Carbonate of Lime.	Carbonate of Magnesia.
Taylor's quarry, near Fountain	9.890	0.240	1.300	86.107	0.470
The Building-stone Layers at Minneapolis	14.450	1.600	1.700	75.482	6.810
The Upper Dolomitic Layers at Minneapolis	16.220	0.375	3.075	54.533	36.002

No analysis has been made, as yet, of the rock furnishing the Spring Valley lime, and it is only from theoretical considerations that that lime is classed here with the "hot limes."*

3. The magnesian limestone of the Galena formation has not been much burned, indeed not so much as its merits demand. It

*Facts obtained since this paper was written indicate that the Spring Valley white lime is a dolomitic rather than a pure lime.

is extensively exposed in many places in Olmsted, Dodge, Fillmore and Goodhue counties. It is generally a buff-colored, vesicular rock. It is burnt for lime only by Mr. Russell Williams, near High Forest, so far as known. This lime is white and fine, and has a good reputation. Probably, were it not for the comparative scarcity of fuel in the region of country where this formations runs in outcrop much more lime would be made from it. In composition it will resemble the limes from the Lower Magnesian, but would be without the large per cent. of unslackable sediment which those limes sometimes possess. It is also of a lighter color, being nearly white.

4. The magnesian limestones of the Upper Devonian are found in outcrop at LeRoy, in Mower county. These layers in their extension through Iowa furnish a great amount of excellent lime, but they are not much used in Minnesota. The lime made from them is white, fine and compact, and has the characters of the "slow limes." The limestones of the Lower Devonian also appear in this State, occupying a large area in the southwestern part of Fillmore county. Lime from these beds is somewhat more open in texture and lighter, and the stone would hence burn easier; but in its action, as well as its color and composition, would not probably differ much from that made from the Upper Devonian, while in texture and weight it would resemble lime made from the Galena. The Lower Devonian beds are largely calcined for lime along their belt of outcrop in central Ohio, and are highly prized for the excellence of the lime produced.

The *Cretaceous* beds that occur at New Ulm and at Red Stone, overlying unconformably the older rocks, contain that part of the formation known as the *Niobrara*, and are burnt for lime. There is a large per cent. of aluminous matter embraced in this lime, but it is so quick in action that this adulteration does not impair the usefulness of the lime. There is also a considerable gypsum included, which imparts to some extent the cementing quality of plaster of Paris. This lime is white, fine and thick to set, and it is preferred by some to the slow-setting limes. It has great strength if it be used before it is partially set. But therein is the difficulty. The great majority of masons are accustomed to the use of the magnesian lime, and have formed fixed habits and notions about the handling of lime and mortar, based on their experience. If a lime acts wrongly with their methods of treatment, it is unhesitatingly condemned, and in some cases by

their testimony is wholly excluded from the markets. This cannot be avoided until the masons themselves are instructed as to the qualities of the various limes they use, and are induced to vary from their routine of making and using mortar.

The boulders of the Drift supply a great deal of the lime used locally in the western part of the State. Several thousand bushels are made annually from this source, and in some cases it is sent by cars into adjoining towns. Almost invariably this lime is of the finest quality, and is sold at the highest prices where it is known. In St. Paul and Minneapolis, however it is not known, and cannot be sold at as high rates as imported lime. These boulders are from a great limestone formation that exists in the northwestern part of the State, and runs north to Winnipeg. In Minnesota it does not appear at all above the drift-sheet. It is a magnesian limestone pertaining to the Upper Silurian or the Devonian, and perhaps to both; and in its extension through Iowa (and southern Minnesota) its parts are well known as the *Cliff Limestone Group* of the early geologists. It is hence the same as that so largely burnt for lime in Iowa and Illinois.

Calcareous Tufa.—At various places in the State are large superficial deposits of calcareous tufa, and in some places this furnishes a strong and quick lime of value to the localities in which it exists. The kilns at Osceola have been run on this deposit partially for many years, but also make a brown lime from the St. Lawrence member of the Lower Magnesian at the same place. The lime made from the tufa is white and strong, being essentially a pure lime. A large deposit of the same kind is to be seen in Tunsbury, Chippewa county, and has been considerably burned for lime and is destined to be used largely for many years to come. The lime made from it is hotter and quicker than that made from boulders. Another similar deposit is found in the south township of Hawk Creek, Renville county; and others near Caledonia, in Houston county, and in Milton, in Dodge county, that at Caledonia being a crystalline travertine, with a lamination and a cross-striation and fibrous structure, like a lamellar calcite. Fragments of the same are found near St. Charles, in Winona county. These are all of modern formation, probably originating from the high-water stage which closed up the glacial period, some of them continuing to grow to the present time.

Brick and Brick-Clay.

There are three main types or classes of clay that are suitable for brick, in the State of Minnessota:

1. The ferruginous laminated clay of the loess-loam and river valleys.
2. The alkaline laminated clay of the loess-loam and river valleys.
3. The Cretaceous alkaline clays.

There are places where the first and second are somewhat mixed, when their product, on being burnt for brick, may be made to vary much in character, color and quality by the length and manner of burning, but in general these clays are quite marked and distinct not only in the manner and locality of occurrence, but in the nature of the brick they produce. The hardpan clay is generally unfit for brick in Minnesota because of its being mixed with stones of all sizes, many of which are limestone and cause the brick to break on the slacking of the lime, either before or after they are put in the wall.

These three clays may be most easily discussed by stating first their origin and distribution. The first two are alluvial drift clays, and their nature depends on the character of the hardpan, or till, drained by the waters that deposited them. The drift (hardpan) came to the State of Minnesota from two sources, and from two directions. One, the earlier, came from the northeast, and is red, owing its origin to the ferruginous shales and clays of the Potsdam about Lake Superior, and to the decay of the ferruginous and igneous rocks of that district. This drift is scattered over the eastern and northeastern part of the State. Of course streams running from this area will, in high water, distribute along their banks, and over their flood-plains a red, ferruginous laminated clay, both in glacial and post-glacial times. The loess-loam, wherever it prevails in that part of the State, partakes of this character and produces red brick. The other direction from which the hardpan clay came was from the northwest. This drift covers the larger part of the State. It is derived from the disintegration and distribution of the alkaline shales and clays of the Cretaceous strata, very largely, as well as from the limestones in the Red river region. Hence we find that the surface water that drains this hardpan is alkaline, and of course the laminated clay that is found along such streams, both in glacial and in post-glacial times, will partake of the nature of the original source, or will be alkaline. This general grouping, therefore, can be made: Streams flowing from the northwest in the northern and central portions of the State will furnish a laminated clay that will ex-

hibit the qualities of the alkaline brick, and all others will exhibit the ferruginous qualities. There are but slight variations from this general statement. The Upper Mississippi drains an alkaline clay region. A clay used for brick near Brainerd is alkaline and furnishes a cream-colored brick. The bricks made in the Red river valley are cream-colored. Those made from the interglacial clays of the Minnesota valley are cream-colored, and exhibit most perfectly the application of the general principle stated. Those made in the Minnesota valley from the alluvium of the present river are not so uniformly cream-colored, but are more frequently red. It seems as if the alkaline quality of the clays is not rapidly carried away now in the waters of this river, but that owing to a heavy coating of rich soil and the consequent protection of the alkaline hardpan clay from the surface drainage, the water does not come into contact with it freely. It is probable, also, that so much of the accessible soluble alkalies of the hardpan have been carried away that the water that now comes over it only receives from it such amounts of lime and iron as it can take up in passing, and that hence the recent alluvium does not fully illustrate the general principle stated. Wells sunk into this hardpan clay, however, in places unaffected by drainage courses, uniformly afford a water more or less alkaline.

The Cretaceous alkaline clay is a marine formation. It is sometimes calcareous, and even changed to limestone largely as in the Niobrara epoch, seen at New Ulm, and sometimes it is arenaceous, as well as carbonaceous. When sufficient carbon accumulated it formed impure lignites, as on the Cottonwood river, and at Redwood Falls; and in some cases the deposit was completely changed from clay to sand, as in the Dakota epoch, or to a pure lignite valuable for fuel, as in some of the lignite beds of the Fort Benton epoch. But by far the greatest part of the Cretaceous beds consists of alkaline shale or clay. It is this which, distributed through the hardpan clay, or till, gives it its marked characters, and which causes the alkaline laminated clays that give the cream-colored bricks of the Northwest. *

* The writer is aware that cream-colored brick are made at Milwaukee, where it is not generally supposed the Cretaceous beds could have affected the clay. But Dr. Andrews, of Chicago, has shown on analysis of water from the till that it is more "saline" than the water from recent clays, or from the surface. This fact, taken in connection with the existence of presumably Cretaceous clay, and lignites in the Grand Traverse region of Michigan, goes to show that probably a large Cretaceous area existed prior to the glacial period in the region east of the Wisconsin granitic area, covering much of northern Michigan and the lower Great Lakes, which was disrupted by the glacial forces, and nearly obliterated. There is no Devonian or Silurian shale or clay that is known to be so charged with alkalies as the Cretaceous beds of the West, to which this effect can be attributed.

The question now naturally arises, how this alkaline quality aids in producing cream-colored brick, especially since on analysis these clays are found to contain iron as well as the red brick clays, and sometimes as much iron as the red brick clays. This question was answered by Mr. E. T. Sweet of the Geological Survey of Wisconsin. In the presence of alkalies, silica is fusible and soluble at lower temperatures than without it. In the burning of the brick the sand, or silica, is fused, and combines chemically with the alkaline ingredients, and the iron present as red peroxide is fused also, and combines with them, making what we see—a cream-colored, ferruginous silicate of the alkalies and allumina. In this case the color of the iron as peroxide is lost in the mass. In the other class of clays, containing no alkalies, the silica and iron do not thus combine, and the color of the peroxide of iron is only intensified by the burning. In those cases where the iron is not wholly taken up the bricks are partially red, or are mottled with red and yellow.

The State of Minnesota is abundantly supplied with brick-clay. The valleys of the Minnesota and Mississippi rivers show at numerous places a very fine clay of inter-glacial age which supplies a cream-colored brick. Such are worked at Brainerd, at Minneapolis, at Carver, Chaska, Jordan. This same clay exists at St. Paul, and is seen in the gravel and drift bluffs where they have been largely excavated between Sibley and Wacouta streets on Fifth street, sometimes reaching sixteen feet in thickness. The brick made in the Red river valley are from an alkaline clay, probably of later date than that employed in the Minnesota and Mississippi valleys, and are, so far as known, of a cream-color; but this industry is not much developed in the Red river valley because of the scarcity of fuel. It would be much better, however, for that section to import wood from the Leaf Hills country, which is near, and use its own brick clay, than to import brick as is now done, from long distances. Large kilns, however, are run at Moorhead.

The bricks manufactured from the recent alluvium of most of the streams in the State, and from the red laminated clays of higher levels in the eastern part, are red. Such brick are made at St. Paul, Mankato, Belle Plaine, Henderson, and in many places in Fillmore, Houston, Olmsted, Goodhue, Wabasha and other counties.

So far as this industry is known at present through the available observations of the Survey, the bricks made in the State may

be classified as follows. A great many observations have been made on brick burned in the northwestern part of the State, that cannot now be tabulated, also in Goodhue, Wabasha and Dakota counties.

Red brick are made at the following places: Alexandria, Hutchinson, St. Peter, New Ulm, Belle Plaine, Henderson, Shakopee, Redwood Falls, Parker's Prairie (Otter Tail county,) Cokato, St. Paul, Albert Lea, LeRoy, Austin, Forestville, Preston, Lanesboro, Chatfield, Rushford, Rochester, Oronoco, Eyota, Pleasant Grove, Byron, Dodge Center, Kasson, Mantorville, Owatonna, Blooming Prairie, Caledonia, LaCrescent, Spring Grove, Money Creek, Lake Calhoun (near Minneapolis,) White Bear (Ramsey county,) Faribault, Prairieville, Northfield, and New London in Kandiyohi county.

Very light red, or pinkish brick, resembling in color the Kasota building-stone, are made at Litchfield and at Evansville, Douglas county; and at Cokato, in Wright county, some of the brick are of a very dark red color, or brownish-red.

Cream-colored or yellowish bricks are made at the following places, generally in large quantities: Chaska, Carver, Jordan, Otsego (Wright county), Glenwood (Pope county,) Fergus Falls, Moorhead, Minneapolis, Brainerd, Shingle Creek, Frankford, Mower county, (some are also red;) Dayton, and Evansville, Douglas county.

A dirty drab or ash-colored brick is made at the following points: Detroit, Henderson, LeSueur; Sec. 2, Lake Mary, Douglas county, and at New Ulm.

The fire-brick of New Ulm is of a color much like the last, but lighter and harder, and speckled with iron. The Terra Cotta clay, formerly employed at Red Wing,, is inter glacial clay found in the higher terrace plain of Hay Creek, near Red Wing, and actually then within the valley of the Mississippi. It corresponds to the brick clay of Carver and Minneapolis, the peculiar product known as terra cotta being due to the manner of treatment. The same manufacturer has more lately resorted to the potter's clay used by the Red Wing Pottery Company, taken from Sec. 2 in Goodhue, Goodhue county.

The Cretaceous strata themselves are often useful for pottery. Establishments that employ this clay are located at Red Wing, Mankato and New Ulm. From this clay could perhaps be made a very superior red or brown pressed brick, but ordinary treatment will produce a light-colored brick. Yet the color and char-

acter of the bricks made from any clay may be made to vary very widely by the admixture of other ingredients, and by a variation in the manner of burning.

The Cretaceous clays of the State, while making a superior quality of brick for building, are probably susceptible of much more extended uses. The experience of Mr. Winkelmann at New Ulm in the manufacture of fire-brick, and of several pottery establishments in the State, indicates that these clays are sometimes more refractory than is implied in the making of cream-colored bricks. In other words, the chief ingredients in some strata seem to be largely alumina and silica. These clays have not been chemically examined by the Survey, and no positive statements can be made as to their adaptation to these other uses. They are of the same age as the New Jersey plastic clays, which are used for making pottery and all refractory materials, as well as bricks for building, and terra cotta for ornamentation.

Brick is one of the best building materials, as it is one of the most common. It is lighter than most building-stone. It is convenient to handle in construction, and makes a very strong and durable wall. It resists fire better than any building-stone, not excepting granite. Its resistance to pressure of course depends on the quality. A poor, red brick will sustain but six or seven hundred pounds per square inch, but a brick of good quality will sustain from one to two thousand pounds per square inch, and one of the first quality, burnt hard, will endure between four and five thousand pounds per square inch. Sandstone ranges between three and five thousand pounds per square inch, and granular limestone between four and five thousand, some reaching ten and twelve thousand.

Conclusion.

In concluding this hasty review of the building materials of the State, so far as they are derivable from the clays and rocks, it seems appropriate to call the attention of builders and quarrymen to a few things that are of importance in the use of our building-stones and clays, but which still sometimes are neglected.

1. Previous to the opening of a quarry the rock in its natural beds should be carefully examined. It there presents the best opportunities for ascertaining its power of resistance under the alternations of heat and cold, moisture and dryness. Some layers will be found to be much better preserved than others. There

they have been subjected to these vicissitudes for thousands of years. There they have been eroded, jostled, compressed, submerged, frozen by the glacial winter, heated with the warmth of tropical summer. If they still endure, and produce prominent features in the topography of the country, they will probably be capable of enduring a few years longer if placed in a structure for the convenience of man. The enduring formations are the sources of our best building-stone, and on opening a quarry a full and scientific description, including a comparison of the different layers, ought to be made of the appearance of the rock in the hands of nature, as testimony to its weathering power. Then may also best be seen the effects of pyrites, an impurity which very much lessens the value of many building-stones otherwise very excellent. Those little yellow crystals, so common in some limestone, appear on freshly quarried surfaces to be of little or no detriment to the stone; but when they are exposed to the air and moisture for a few months they become converted from sulphuret of iron to a peroxide, and their rusty drippings are very offensive to the eye.

Permanence of color may also be observed best at the natural outcrop of the rock. Before demolition by the weather a rock assumes different colors. Whatever may be the color of a stone fresh from the quarry it cannot be permanent. Most of our limestones show three different colors, according to the degree of exposure and the ease of access within of the air and water. For instrnce, the Galena limestone, in the southern part of our State, in the river bluffs, is of a dark buff, or rusty-buff, color on the long-weathered surface. This color pervades that portion of the stone that is undergoing rapid disintegration in its natural beds, and is generally not more than half an inch in depth. Under that is the light buff color seen in most of the stone quarried and used from that formation, and it pervades the stone to a great depth. Where the texture is open this color has apparently gone through all the beds. But it is an acquired color, or one produced on the rock by atmospheric causes. Deep within the quarries may finally be seen the natural color, where exposure has not yet produced any change. It is blue, and at first is seen only in the center of the layers, surrounded by a layer of the light color. These different colors can be seen in the Trenton, quarried at St. Paul and Minneapolis. But owing to the close clayey nature of this formation the blue color is better preserved, and is that seen in the stone now most used. Formerly the stone used was of a

dirty-drab or yellowish color, very largely, owing to the newness of the quarries, which had not yet penetrated below the natural weathering.

2. Among architects and stone-cutters there is an inexcusable, and sometimes criminal, disregard of scientific authority. The reckless haste of modern times is nowhere better illustrated,—too often to our sorrow, alas!—than in the construction of our buildings. It consists not only in the style and manner of building, but in the choice of materials. The boasted science of modern times is often perverted so as rather to teach how to transgress science. Some builders denounce the best stone or the best quicklime, and advocate that most easily worked. They get the ear of their employer by urging the quickness of construction and the cheapness of the inferior article. The builder is often the only one who has any opinion to express, and he finds little difficulty in dictating the choice of material. If he is regardless of the great responsibility of his position he may entail great loss on his employer, or even cause the loss of human life. Every city like Minneapolis or St. Paul should have some control over the large structures annually put up within their limits, not only as regards their being fire-proof within certain areas, but as regards the methods of construction and the combination of material. There should be an examiner of buildings, free from financial connections with construction, and an able architect, charged with the constant inspection of such structures as are now going up. The lessons of the past give us warning of such a necessity.

3. In the use of the Trenton limestone quarried at St. Paul and Minneapolis, regard should be had constantly to its laminated structure. The beds quarried now are as they were originally deposited, and as cut for use embrace in every block many layers of from ½ to 2 inches in thickness. These consist of alternating clayey and calcareous portions, the latter constituting the hard and enduring part of the stone. These layers are not always distinct and continuous over large surfaces, but they blend or shade into each other every few inches. Yet in process of time, under natural weathering, they get separated so as to fall apart, the clayey parts disintegrating first and causing the calcareous structure which sustains the whole to break up into small sheets or fragments. Hence this stone should never be placed on edge, but in the same position it occupied in the

quarry. It should never be allowed to occupy projecting or exposed parts of a building. Most especially if it be on edge and in a projecting cornice or capital, it is the source of weakness to the structure, as well as of danger to all passers, from the dropping of sheets or fragments as the weather by wet and frost separates them from each other. Its color also is against its being put into the exposed and ornamental parts of a structure. In the more ornamental parts of a structure the stone employed should be of fine grain and texture, and of a light color, that the shadows may not be lost. The color of the Trenton makes it very suitable for foundations, and for the ranges below the water-table, but even there it should be well bedded in mortar and protected by the water-table, in order to keep out water.

4. All builders and architects of the State ought to have regard for the products of our own quarries, and to avoid the importation of foreign stone when suitable material can be got within the limits of Minnesota. The foregoing pages are intended to give some idea of the qualities of our building-stones. We have nothing of the color and composition of the Ohio freestone which is now being introduced in St. Paul and Minneapolis. It seems, however, to have been chosen in some instances where some of our own building-stones would have been as good, or even better. The light and lively color of the cut-stone from Frontenac is equally agreeable, even in a light brick structure, and is less liable to have its corners chipped in handling or subsequently. The brown freestone of Fond du Lac, near Duluth, is very firm, and a very useful building stone. It is suitable in any structure. If it were to be generally used in such places where the Trenton stone is now used, or in trimmings for buildings built of brick, particularly of red brick, it would give very good satisfaction. It will make very fine fronts to business blocks. The new Westminster Church at Minneapolis is being built of it. The well-known Kasota stone, and the Red Wing stone, are extensively employed for sills, caps, water-tables, pillars, front steps, flagging, and all construction, and cannot be surpassed for durability or for beauty. It is to be hoped that the present fashion for using Ohio stone, at great cost for transportation, will be only temporary, and that influential builders will see to it that our own equally good stone is not allowed to remain unused. It cannot be anything more than a mere sentiment, that prefers foreign products over domestic, that will cause the continued importation of stone

from abroad, to the neglect of the building-stones of Minnesota. After a few years exposure in cities the Ohio stone becomes dirty, dingy, dusty, and generally disagreeable, while a brown sandstone maintains its color, and always gives an impression of solidity and durability; while under the bright and cloudless skies of Minnesota its dark and more sombre aspect is far less objectionable than in darker and damper atmospheres.

Respectfully submitted,

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The University of Minnesota,
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