In the Kentucky Geological Survey Publication, Ser. 6, v.15 (Frankfort, 1923), *Geological Research in Kentucky* by Willard Rouse Jillson, the author cites the inclusion of 1 map with Robert Peter's publication, *Comparative Views of the Composition of the Soils, Limestones, Clays, Marls, &tc., of the Several Geological Formations of Kentucky, as Shown by the Chemical Analyses Published in the Several Reports of the Geological Survey of the State...* (1883).

Four copies at this publication at the University of Kentucky do not include a map. Copies of this publication at the U. S. Geological Survey Library and the University of Chicago Library similarly lack this map.

Adelaide Hasse in *Index of Economic Material in Documents of the States of the United States, Kentucky 1792-1904,* Washington, D.C.: Carnegie Institution of Washington, 1910, presents a nearly comprehensive overview of the KGS publications. Hasse does not include the map in her description of this publication.

The text makes no reference to map.

GEOLOGICAL SURVEY OF KENTUCKY.

JOHN R. PROCTER, DIRECTOR.

COMPARATIVE VIEWS OF THE COMPOSITION

OF THE

SOILS, LIMESTONES, CLAYS, MARLS, &C., &C.,

OF THE

SEVERAL GEOLOGICAL FORMATIONS

OF KENTUCKY,

AS SHOWN BY THE CHEMICAL ANALYSES PUBLISHED IN THE SEVERAL

REPORTS OF THE GEOLOGICAL SURVEY OF THE STATE.

WITH REMARKS ON THEIR CHARACTERS AND PRACTICAL USES.

BY ROBERT PETER, M. D.,

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1883.

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INTRODUCTORY LETTER.

LABORATORY OF KENTUCKY GEOLOGICAL SURVEY
AND OF KENTUCKY STATE COLLEGE,
LEXINGTON, KY., April, 1883.

MR. JOHN R. PROCTER,
Director of Kentucky Geological Survey, &c.,

DEAR SIR: I herewith send you such comparative views of the composition of the Soils, Limestones, Clays, Marls, &c., of Kentucky as I have been able to obtain from the various characteristic specimens which have been analyzed in this laboratory during the progress of our Geological Survey, from its commencement in 1854, under the late Dr. D. D. Owen, down to the time of the latest published report of the work of the Survey.

Yours, respectfully,
ROB'T PETER.

A COMPARATIVE VIEW OF THE SOILS ON THE VARIOUS GEOLOGICAL FORMATIONS OF KENTUCKY.

In the study of Kentucky soils, and the numerous chemical analyses which have been made of them during the progress of the Geological Survey of the State, some facts of interest have been ascertained.

That all soils have been primarily produced by the disintegration of rock strata is now universally admitted. But, as the débris of rocks is continually transported, by water and other agencies, from higher to lower levels, and as, during the so-called glacial epochs of geological history, the bodies of ice, which covered a great portion of our northern hemisphere, caused the transfer of an immense amount of these soil materials, few localities present any large area of soil which has been formed where it is at present found by the decomposition of the rock strata in place.

Kentucky is quite exceptional in this respect, as compared with the extensive regions to the north and west of our State. The valley of the Ohio river seems to have been the limit beyond which could not be carried the great mass of mixed materials—clay, sand, gravel, and bowlders of all sizes—derived generally from rocks in place in the far Northwest, which cover the surface on this whole vast territory, so that the superficial deposit which constitutes the soil generally bears no relationship to the rock strata beneath.

Most of the soils of Kentucky have been formed from the rock strata of their immediate vicinity, being what are termed *sedentary soils*, and hence generally show a relationship in composition to the geological formations on which they rest, except such of them found in the valleys and low grounds of the rivers and streams, made up of more recently transported materials, which come under the name of *alluvial soils.*

Kentucky is somewhat peculiar in another important circumstance. The superficial rocks from which her soils were produced seem, with very few exceptions, as in the case of the coarse sandstones and conglomerate rocks of our coal-measure strata, to have been primarily deposited and formed under the waters of a primeval ocean, at such a distance from the shores, and under such circumstances, as that none but earthy or sandy materials in the finest state of division, entered into their composition, and large relative proportions of lime, magnesia, clay, phosphates, &c., are found in them. Pebbles, gravel, coarse sand, or fragments of rock are rarely present, except in some of the soils of the coal-measures. In most cases, in the large number of soils analyses which have been made of Kentucky soils during the progress of the Geological Survey, the dry earth passed wholly through a sieve having sixty-four meshes to the centimeter square; and, after this fine earth had been submitted to the solvent action of acids, the remaining "sand and insoluble silicates" were fine enough to pass through a fine sieve having about 1,600 meshes to the centimeter square—finer than ordinary bolting-cloth. Indeed, this silicious residue of our best soils is so fine that it is not generally recognized as sand, and although it is readily permeated by water, it presents some of the adhesive and absorptive properties of clay. Sand, so-called, is not to be found in the beds of the local streams where this soil prevails, and building sand must be imported.

Many Conditions must Concur to Give Fertility to Soils.

1. *Meteorological.*—The climate, as to temperature, amount of rain-fall, &c., &c., presents important conditions essential to fertility.

2. *Location.*—Land at the bottom of a slope receives the washings and finer, richer materials from the uplands. It is well known that the atmospheric and soil waters, passing through continually, carry these fertilizing materials to the lower levels. The upper slopes are thus continually leached and impoverished, while, as is sometimes observed in our own

State, the soil on the high level summits of hills is richer than that of the inclined valleys which drain their flanks.

3. *Drainage.*—No soil sodden with water can be productive of crops, however rich it may be in the elements of fertility. Kentucky is peculiarly fortunate in the fact that the great body of her soils are naturally drained. This is especially the case in the so-called "Blue Grass" soil, which, on somewhat elevated table-land, is underlaid by limestone containing numerous crevices and caverns, which carry off the surplus water. But in some few localities, especially where the black slate formation prevails, the disintegration of which produces a tough clay very retentive of water, the injurious effects of too much water are evident. The soil may be found to be quite rich in the elements of plant food, but is not correspondingly productive for want of drainage.

No better example of this can be given than that of a soil in Wayne county, based on the Sub-carboniferous Limestone formation, collected by the late Dr. Owen, and analyzed by the present writer in 1856 (see Rept. Ky. Geol. Surv., O. S., vol. 2, p. 273), which has the chemical composition of quite a rich soil, and is almost black because of its more than 21 per cent. of organic and volatile matters, but which was unproductive for "want of draining and access of air"—in the language of Dr. Owen, who added that with the aid of lime and a proper system of drainage, "I venture to predict it will become one of the most productive soils in the State."

Extensive experience in England, and in the older settled regions of this country, has demonstrated the great utility of underdraining the soil. Without attempting to describe the best methods of underdraining land, we will briefly state some of its benefits: 1. In allowing the excess of water to escape continually, it not only removes this one cause of sterility, but tends to increase the porosity of the soil and the area through which the roots of plants may spread and obtain nourishment. 2. Because the body of the soil, during the growing season, is constantly colder than the superincumbent atmosphere, a current of cold air is continually flowing out of the open mouths of the drain pipes, which is supplied by warmer air from above. This continued slow circulation of air through the cool soil not only causes the drained soil to become earlier warmed in the spring than the undrained soil, but brings to the growing vegetation a constant supply of the gases and vapors of the atmosphere which are essential to plant growth. The warm air, full of vapor of water, also deposits in the soil a considerable amount of water, which is condensed on passing through the colder soil; so that the underdrained soil does not suffer so much from droughts as the undrained. 3. The abundant supply of air also favors those chemical changes of decomposition and recomposition by which the elements of fertility are brought into an available condition for the nourishment of plants.

4. *Physical conditions.*—The soil, to be fertile, must be in a state of fine division; coarse sand, gravel, or fragments of rock give little or no plant nourishment, and are usually excluded, by all agricultural chemists, from their estimate of the value of a soil. The "fine earth" only is taken into account or analyzed. Thus, in the annexed table of soil averages, the conglomerate soils, which contain an average of 20.7 per cent. of gravel or pebbles, must have their estimated value (based on the analyses of their "fine earth") discounted in this proportion. So, in the comparison of our rich "Blue Grass" soil with the very rich volcanic soil of Auvergne (see tables), a discount of 16 per cent. must be made from the latter for the same reason.

Moreover, as a large proportion of the food of plants is derived from the atmosphere directly or indirectly, no soil, however rich it may be, can be very productive unless it is in a porous condition. On this fact, fully demonstrated by long experience, are based many of the practices of the husbandman in stirring, loosening, and cultivating the soil, especially during the growing season.

5. *Chemical conditions.*—Soils, to be fertile, must contain clay and fine sand, mixed in such proportions as that, while readily permeable by water, they may yet be, to a certain degree,

adhesive. Pure sand and pure clay do not offer favorable conditions for vegetable growth; such a mixture of them as forms what is called a loam soil is generally considered the best. Fertile soils must also contain a certain proportion of organic matters, known generally by the name of *humus*, a mixture of substances derived from the decay of vegetable and animal matters, which gives the dark color to the soil as compared with the subsoil and the almost black hue to the rich garden mould. Humus makes the soil more light and porous, and possesses the power of absorbing the gases and vapors of the atmosphere, water, and dissolved natural fertilizers in a higher degree than any other ingredient of the soil. Undergoing a gradual oxidation, it furnishes carbonic acid, nitrogen compounds, and water, and by the ozone it forms during this process, favors the production of nitrogen compounds from the atmospheric elements. It holds ammonia, potash, phosphates, &c., against the leaching action of the atmospheric waters, yielding them readily to the rootlets of plants, and, by the acids it produces, in its ulterior state of decomposition, it aids in dissolving the essential mineral elements of the soil, making them available for plant food.

It has been the fashion, in recent times, to underrate the value of humus in the soil, blindly following the teachings of Liebig, who gave too exclusive importance to the mineral elements of fertility; but practical experience is corroborated by scientific investigation in giving a high value to humus as an ingredient of a fertile soil. "The latest conclusions of agricultural chemists are, that the excess of nitrogen in the crop over that contained in the soil is caused by the action, on the atmospheric elements, of the carbonaceous matters of the soil" (the humus).—Quoted from article "TERRES ARABLES" in *Wurtz's Dictionnaire de Chemie, &c.*

In this connection we are tempted to quote from a recent publication of Peter Henderson, of New York, one of the most experienced and enlightened gardeners in the country, the results of his observations and practical experiments. After stating that the concentrated commercial fertilizers "will not do" for any great length of time to maintain fertility without the aid of stable manure, or some other means of improving what he terms the "physical condition of the soil," he states: "hence experienced market gardeners near New York rotate their fields." Of twenty acres they keep five in grain, clover, and grass, "to be broken up successively every second or third year, so as to get the land in the condition that nothing else but rotted, pulverized sod will accomplish." (*Humus.*) "This is done where the land is worth five hundred dollars per acre. Experience having proved that with one quarter of the land resting under grass more profit can be got than if the whole were under culture." And this in the region where they habitually apply several hundred dollars' worth of commercial fertilizers to the acre per annum.

In our newer country, where land is cheap, too little attention is paid to fallow and rotation of crops, which both may serve to renew the humus which has been removed in the cultivation of the hoed crops. Fallow, or allowing the land to rest, need not be a "*naked fallow,*" or letting it rest with no other crop but weeds, but could more profitably be a "*green fallow,*" combined with rotation when clover or grass are cultivated, to be fed to stock, and subsequently plowed under to increase the amount of humus and otherwise improve the soil. And when small grain of any kind is raised in the rotation, the straw, instead of being burnt up out of the way of the farmer, could be more profitably used on the English plan, in a so-called straw-yard, where it is fed to stock and trampled into valuable manure, to be hauled to the fields in the early spring.

It is now a well-established fact that cultivated soils require constant renewal of their elements of fertility, especially when the crops are habitually removed, and no return of manures are made to the soil. How most economically to effect this renewal is a practical question with most farmers, and one of great interest to the agricultural chemist.

Besides the humus and certain other atmospheric elements above mentioned, certain other ingredients, called the mineral elements of fertility, are equally indispensable to the fertility of the soil and to vegetable growth. These are phosphoric acid, potash, lime, magnesia, sulphur, chlorine, iron, and others, in such a state of combination as to be available for plant nourishment.

Of these, all are alike essential as necessary elements in the composition of the vegetable. Yet, as some of them are found in very small proportions in soils, and are habitually carried off in the crops, such as the phosphoric acid and potash, the practical agriculturist holds these as the most essential, knowing that the other essential elements of the soil are usually present in it in inexhaustible quantities, or are continuously supplied from the atmosphere. Hence the value of a commercial fertilizer, in renovating an exhausted soil, depends mainly on its relative quantities of available phosphoric acid, of potash, and of nitrogen compounds, especially, also, because these ingredients only will bear the cost of transportation to any great distance, and the others are frequently to be found near the farm.

The farmer who consumes most of his products at home has usually little need of any fertilizers but those which are furnished by his stables, compost heaps, or cess-pools, properly utilized; or by a judicious rotation of crops and feeding of his stock on his fields. But the commercial farmer, whether he cultivates that most exhausting and damaging crop, tobacco, or annually exports his cotton, hemp, potatoes, corn, or other grain, or simply sells his live stock raised on the farm, correspondingly robs his soil of its essential elements of fertility, and, especially if he does not rotate his crops, must resort to commercial fertilizers to maintain its productiveness. The nature and quantity of these will depend on the composition of his soil and the character of his products sold off the farm; but available phosphates, compounds of potash, and nitrogen compounds are their most valuable ingredients. Marls, when near at hand, may be advantageously employed, in quantity, to modify the physical character of soils, and to supply lime when deficient, and potash and phosphates in some cases.

Lime, ground or burnt and slacked, proves useful also on some soils, especially when, like the blue limestone it contains notable proportions of phosphates, potash, &c.; but both of these will not bear long transportation.

Although the clay and the sand of the soil are not actually elements of plant food, yet they, in proper mixture, are essential in furnishing the medium in and by which they obtain nourishment and growth, while the iron oxide which enters into the composition of the vegetable is almost always present in superabundance in the soil. The oxide of iron aids essentially in facilitating decomposition of organic matters, in the formation of fertilizing nitrogen compounds and by its great absorptive power. It is doubted by most agricultural chemists whether silica (the material of sand) is an essential article of plant food; yet it is present in notable quantity in all plants, especially in those of the family of grasses, and in the form of sand is necessary to the porous structure of soil.

WHAT IS THE CHEMICAL COMPOSITION OF A FERTILE SOIL?

This question may be answered by reference to the appended Tables. (*See Summary of the Averages of the Kentucky Soils from Different Geological Formations, &c.*) The composition represented by the mean of the averages of the 234 Kentucky soils which were taken for comparison, represents, no doubt, that of soil of *rather more than average fertility*.

According to Mr. P. De Gasparin (a well known French authority):

0.20 per cent. of phosphoric acid in a soil makes it	*very rich.*
0.10 per cent. and upwards makes it	*rich.*
0.05 per cent. makes it	*poor.*
Between 0.1 and 0.05 per cent. makes it	*medium.*

Schlœssing's *average* of phosphoric acid in soils is 0.17 per cent. The richest volcanic soils contain 0.60 per cent., and the poorest soils quoted by Gasparin had only 0.09 or less per cent.

The proportions of potash, in relation to fertility, vary in nearly the same manner. Mr. P. De Gasparin, in his "*Traite* *des Terres Arables*," gives the proportion of 0.14 per cent. of potash as a normal average quantity, and quotes, in the case of the volcanic soil of the vineyard of Lacryma-Christi, on the flanks of Vesuvius, the enormous percentage of 3.47 of potash in the fine earth. This, however, is to be discounted by 34. per cent. for pebbles present in this soil. Our richest Blue Grass soil or subsoil sometimes contains more than 0.70 per cent. in the virgin soil, and upwards of 1.00 per cent. in the subsoil or under-clay, and has no pebbles. The poorest Kentucky soil analyzed contains only 0.021 per cent. of *potash.*

By reference to the appended tables of the relative composition of the richest and poorest soils of Kentucky, and the examples of foreign soils which "are very fertile," the significance of the other tables of the composition of the soils on the several geological formations of Kentucky may be readily appreciated:

TABLE A.

AVERAGE COMPOSITION OF THE SOILS ON THE SEVERAL GEOLOGICAL FORMATIONS OF KENTUCKY.

	Organic and volatile matters.	Alumina and iron and manganese oxides.	Lime carbonate.	Magnesia.	Phosphoric acid (P_2O_5).	Potash, extracted by acids.	Sand and insoluble silicates.	Water expelled at 212° F.	Potash in the insoluble silicates.	Rock fragments, gravel, pebbles or sand.
(1.) ALLUVIAL SOILS.										
Lewis Co. (Ohio R. Valley). Vol. IV, N. S., pp. 105–6—average of 3 soils	3.472	9.835	0.102	0.189	0.118	0.450	84.310	2.513	1.405	0
Fulton Co. (Mississippi R. Valley). Vol. V, N. S., p. 424—average of 2 soils	9.305	10.437	1.385	.461	.198	.142	74.840	4.100	1.889	0
(2.) QUATERNARY (LOESS) SOILS.										
Ballard Co. Vol. V, N. S., p. 409—average of 7 soils and subsoils	2.673	5.713	.431	.351	.112	.263	88.798	1.871	1.535	0
Fulton Co. Vol. V, N. S., p. 425—average of 9 soils and subsoils.	3.410	6.450	.437	.143	.120	.193	87.850	2.132	1.911	0
McCracken Co. Vol. V, N. S., p. 222—average of 5 soils and subsoils	2.458	9.543	.165	.479	.086	.365	87.765	3.083	1.577	0
Average of the 21 Quaternary soils	2.937	6.941	.370	.292	.118	.257	88.098	2.271	1.706	0
(3.) COAL-MEASURES SOILS.										
In the Old Series of Ky. Geol. Repts.—average of 40 soils and subsoils.	4.234	5.821	.221	tr.	.134	.221	87.774	n. e.	n. e.	n. e.
Carter Co. Vol. 1, N. S., p. 195—average of 4 soils and subsoils.	3.067	5.038	.111	.050	.149	.210	90.567	1.285	. . . .	2.200
Daviess Co. Vol. IV, N. S., p. 57—average of 6 soils and subsoils.	3.823	7.861	.140	.082	.100	.263	86.531	1.989	. . . .	n. e.

Hopkins Co. Vol. IV, N. S., p. 89—average of 9 soils and subsoils	4.172	6.966	.223	.127	.076	.323	87.422	1.639	1.306	n. e.
Rockcastle Co. Vol. V, N. S., p. 468—1 soil . .	6.890	7.126	.345	.223	.109	.366	82.690	2.085	.925	14.500
Average of the 60 Coal-measures soils	4.150	6.166	.208	.103	.134	.244	87.698	1.695	1.268	. . . .
(4.) CONGLOMERATE OR MILLSTONE GRIT SOILS.										
Rockcastle Co. Vol. V, N. S., p. 469—No. 2231 .	4.150	3.877	.085	.120	.083	.100	90.665	.900	.671	21.400
Whitley Co. Vol. IV, N. S., p. 146—No. 1961 .	3.075	3.429	.115	.080	.061	.194	91.105	1.200	.692	20.000
Average of the 2 Conglomerate soils.	3.612	3.653	.100	.100	.072	.147	90.885	1.050	.681	20.700
(5.) UPPER SUB-CARBONIFEROUS SOILS.										
Crittenden Co. Vol. V, N. S., p. 418—average of 4 soils and subsoils.	2.830	6.347	.186	.345	.087	.173	88.825	. . . .	. . . .	n. e.
Grayson Co. Vol. I, N. S., p. 233—average of 6 soils and subsoils	3.929	7.343	.181	.159	.160	.200	87.230	2.229	1.199	n. e.
Hardin Co. Vol. I, N. S., p. 253—average of 25 soils and subsoils.	2.838	9.191	.257	.237	.129	.270	86.438	1.735	.885	n. e.
Logan Co. Vol. V, N. S., p. 215—average of 7 soils and subsoils.	3.067	7.105	.291	.204	.101	.158	88.113	2.260	1.266	n. e.
Average of the 42 Upper Sub-carboniferous soils,	3.031	8.308	.245	.235	.125	.232	87.058	1.910	1.005	n. e.
(6.) LOWER SUB-CARBONIFEROUS SOILS.										
Adair Co. Vol. 2, O. S., p. 129—1 soil.	4.440	4.841	.196	.046	.065	.075	90.446	. . . .	. . . .	n. e.
Bath Co. Vol. 3, O. S., p. 77—average of 4 soils and subsoils	4.551	6.800	.132	.395	.158	.158	88.605	. . . .	. . . .	n. e.
Average of the 5 Lower Sub-carboniferous soils,	4.529	6.408	.145	.325	.159	.161	88.973	. . . .	. . . .	. . . .
(7.) WAVERLY OR KNOB FORMATION SOILS.										
Hardin Co. Vol. 3, O. S., p. 285—average of 4 soils and subsoils.	2.644	4.307	.116	.232	.108	.109	92.334	n. e.	n. e.	. . . .
Monroe Co. Vol. 2, O. S., p. 246—1 soil. . . .	4.130	4.936	.106	.200	.075	.119	89.393	n. e.	n. e.	. . . .

TABLE A.—AVERAGE COMPOSITION OF SOILS—Continued.

	Organic and volatile matters.	Alumina and iron and manganese oxides.	Lime carbonate.	Magnesia.	Phosphoric acid (P2 O5).	Potash, extracted by acids.	Sand and insoluble silicates.	Water expelled at 212° F.	Potash in the insoluble silicates.	Rock fragments, gravel, pebbles, or sand.
(7.) WAVERLY OR KNOB SOILS—Continued.										
Rowan Co. Vol. 4, O. S., p. 253—average of 2 soils and subsoils.	4.629	2.972	0.207	0.295	0.086	0.295	88.470	n. e.	n. e.	. . . .
Russell Co. Vol. 2, O. S., p. 259—1 soil	4.170	4.478	.176	.066	.088	.063	90.786	n. e.	n. e.	. . . .
Taylor Co. Vol. 3, O. S., p. 395—average of 2 soils and subsoils.	6.445	5.157	.147	.429	.126	.135	86.337	n. e.	n. e.	. . . .
Average of the 10 Waverly soils.	4.102	4.290	.145	.264	.101	.148	89.913	n. e.	n. e.	. . . .
(8.) BLACK SLATE (OHIO SHALE) SOILS.										
Bullitt Co. Vol. 3, O. S., p. 227—1 soil.	5.665	7.432	.196	.526	.253	.258	85.056	n. e.	n. e.	. . . .
Madison Co. Vol. 4, O. S., p. 213—1 soil . .	6.125	13.230	.095	.385	.271	.121	79.270	n. e.	n. e.	. . . .
Madison Co. Vol. 4, O. S., p. 214—average of 3 soils and subsoils	10.513	11.487	.845	.907	.222	.088	74.470	. .	n. e.	. . . .
Madison Co. Vol. V, N. S., p. 221—1 soil. . .	5.825	10.434	.615	.043	.301	.379	78.965	1.537	n. e.	. . . .
Marion Co. Vol. 4, O. S., p. 313—average of 3 soils and subsoils.	4.405	9.910	.280	.337	.207	.183	84.827	n. e.	n. e.	. . . .
Average of the 9 Black Slate soils	5.929	10.587	.475	.524	.234	.178	80.131	. . . .	. . . .	. . . .
(9.) CORNIFEROUS LIMESTONE SOILS.										
Jefferson Co. Vol. 4, O. S., p. 192—average of 6 soils and subsoils.	4.158	6.615	.304	.563	.350	.229	87.355	. . . .	. . . .	0
Madison Co. Vol. V, N. S., p. 454—average of 3 soils and subsoils.	5.113	10.763	1.318	.653	.287	.517	79.428	3.208	1.776	0

Nelson Co. Vol. 4, O. S., p. 232—average of 6 soils and subsoils	5.965	10.655	.209	.676	.257	.395	81.720	n. e.	n. e.	n. e.
Average of the 15 Corniferous Limestone soils,	5.071	9.060	.469	.626	.279	.343	83.517	. . . .	. . . .	. . . .
(10.) UPPER SILURIAN SOILS.										
Bath Co. Vol. 4. O. S., p. 73—average of 4 soils and subsoils	6.486	10.759	.314	.554	.204	.249	84.429	n. e.	n. e.	n. e.
Fleming Co. Vol. 4, O. S., p. 152—average of 3 soils and subsoils	8.775	16.188	.428	.807	.223	.330	69.928	n. e.	n. e.	n. e.
Jefferson Co. Vol. 2, O. S., p. 220—average of 5 soils and subsoils	5.548	9.771	.279	.249	.223	.215	84.269	n. e.	n. e.	n. e.
Lewis Co. Vol. 4, O. S., p. 199—average of 4 soils and subsoils	4.935	6.857	.304	.467	.112	.203	87.360	n. e.	n. e.	n. e.
Average of the 16 Upper Silurian soils	6.234	10.493	.322	.422	.190	.242	82.395	n. e.	n. e.	n. e.
(11.) SILICIOUS MUDSTONE (OR MIDDLE HUDSON) SOILS.										
Fayette Co. Vol. 2, O. S., p, 162—1 soil.	4.881	10.306	.276	.133	.254	.139	83.834	4.12	n. e.	n. e.
Grant Co. Vol. 3, O. S., p. 272—average of 4 soils and subsoils	4.764	6.115	.209	.421	.216	.181	87.784	n. e.	n. e.	n. e.
Owen Co. Vol. 4, O. S., p. 245—average of 6 soils and subsoils	4.771	7.157	trace.	.807	.162	.142	86.182	n. e.	n. e.	n. e.
Average of the 11 Middle Hudson soils	4.778	7.064	.101	.605	.165	.155	86.551	n. e.	n. e.	n. e.
(12.) LOWER SILURIAN (TRENTON) LIMESTONE SOILS ("BLUE GRASS SOILS").										
Bath Co. Vol. 4, O. S., pp. 72-75—average of 4 soils and subsoils	7.895	8.664	.543	.665	.369	.315	81.690	n. e.	n. e.	0
Bracken Co. Vol. 4, O. S., pp. 84-91—average of 4 soils and subsoils	6.760	11.716	.839	1.338	.290	.304	77.537	n. e.	n. e.	0
Clark Co. Vol. 4, O. S., p. 115—average of 6 soils and subsoils	6.814	11.086	.383	.807	.275	.475	79.057	n. e.	n. e.	0
Fayette Co. Vol. 1, O. S., pp. 276-8—average of 2 soils and subsoils	6.990	11.034	.783	.250	.422	.172	80.170	n. e.	n. e.	0

TABLE A.—AVERAGE COMPOSITION OF SOILS—Continued.

	Organic and volatile matters.	Alumina and iron and manganese oxides.	Lime carbonate.	Magnesia.	Phosphoric acid (P_2O_5).	Potash, extracted by acids.	Sand and insoluble silicates.	Water expelled at 212° F.	Potash in the insoluble silicates.	Rock fragments, gravel, pebbles, or sand.
(12.) Lower Silurian (Trenton) Limestone Soils ("Blue Grass Soils")—Continued.										
Fayette Co. Vol. I, N. S., p. 204—average of 2 soils and subsoils.	6.457	8.545	.592	.343	.433	.208	82.403	n. e.	1.080	0
Fayette Co. Vol. IV, N. S., pp. 66–8—average of 5 soils and subsoils	4.874	13.329	.454	.278	.414	.504	78.558	2.733	.972	0
Fleming Co. Vol. 4, O. S., p. 153—average of 3 soils and subsoils.	6.143	12.077	.545	.705	.287	.565	79.378	n. e.	n. e.	0
Mason Co. Vol. 4, O. S., p. 217—average of 3 soils and subsoils.	6.606	9.422	.269	.741	.229	.483	81.520	n. e.	n. e.	0
Woodford Co. Vol. 4, O. S., p. 281—average of 3 soils and subsoils	6.578	13.359	2.891	.287	.347	.366	75.098	n. e.	n. e.	0
Average of the 32 "Blue Grass soils"	6.211	11.200	.749	.644	.328	.404	73.380	. . . .	. .	. . . .
(13.) Birdseye Limestone Soils.										
Garrard Co. Vol. 3, O. S., pp. 303–4—average of 2 soils	3.973	6.455	.667	.583	.249	.228	82.160	n. e.	n. e.	0
Jessamine Co. Vol. 4, O. S., pp. 157–8—average of 4 soils	4.493	6.542	.320	.282	.186	.153	87.620	n. e.	n. e.	
Average of the 6 Birdseye Limestone soils . .	4.453	6.513	.453	.383	.207	.178	85.800	. . . .	. . . .	. . . .

TABLE B.

SUMMARY OF THE AVERAGES OF THE KENTUCKY SOILS FROM THE VARIOUS GEOLOGICAL FORMATIONS.

	Organic and volatile matters.	Alumina and iron and manganese oxides.	Lime carbonate.	Magnesia.	Phosphoric acid (P_2O_5).	Potash, extracted by acids.	Sand and insoluble silicates.	Water expelled at 212° F.	Potash in the insoluble silicates.	Rock fragments, gravel, pebbles, or sand.
(1.) Average of 3 Ohio Valley Alluvial soils .	3.472	9.835	0.102	0.189	0.118	0.450	84.310	2.513	1.405	0
Average of 2 Miss. Valley Alluvial soils .	9.305	10.437	1.385	.461	.198	.142	74.840	4.100	1.889	0
(2.) Average of 21 Quaternary (Loess) soils. .	2.937	6.941	.370	.292	.118	.257	88.098	2.271	1.706	0
(3.) Average of 60 Coal-measures soils	4.150	6.166	.208	.103	.134	.244	87.698	1.695	1.268	n. e.
(4.) Average of 2 Conglomerate soils	3.612	3.653	.100	.100	.072	.147	90.885	1.050	.681	20.700
(5.) Av'ge of 42 Upper Sub-carboniferous soils,	3.031	8.308	.245	.235	.125	.232	87.058	1.910	1.005	n. e.
(6.) Av'ge of 5 Lower Sub-carboniferous soils .	4.529	6.408	.145	.325	.159	.161	88.973	n. e.	n. e.	n. e.
(7.) Average of 10 Waverly soils	4.102	4.290	.145	.264	.101	.148	89.913	n. e.	n. e.	n. e.
(8.) Average of 9 Black Slate soils.	5.929	10.587	.475	.524	.234	.178	80.131	n. e.	n. e.	n. e.
(9.) Average of 15 Corniferous Limestone soils,	5.071	9.060	.469	.626	.279	.343	83.517	n. e.	n. e.	0
(10.) Average of 16 Upper Silurian soils. . . .	6.234	10.493	.322	.422	.190	.242	82.395	n. e.	n. e.	0
(11.) Average of 11 Silicious Mudstone (Middle Hudson) soils	4.778	7.064	.101	.605	.165	.155	86.551	n. e.	n. e.	n. e.
(12.) Average of 32 Trenton ("Blue") Limestone soils.	6.211	11.200	.749	.644	.328	.404	73.380	n. e.	n. e.	0
(13.) Average of 6 Birdseye Limestone soils . .	4.453	6.513	.453	.383	.207	.178	85.800	n. e.	n. e.	0
Average of the 234 Kentucky soils	4.470	7.998	.355	.336	.177	.262	84.632	. . . .	. . . .	. . . .

TABLE C.

COMPOSITION OF TWO OF THE POOREST SOILS OF KENTUCKY.

Old field soil, Hardin Co.—No. 644	2.309	3.356	.097	.191	.078	.075	93.495	1.500	n. e.	1.60
Virgin soil, Wayne Co.—No. 2253.	1.850	2.836	.195	.073	.029	.021	94.590	.440	.711	33.40

TABLE D.

COMPOSITION OF THREE OF THE RICHEST SOILS OF KENTUCKY, ON THE LOWER SILURIAN LIMESTONE, &C.

	Organic and volatile matters.	Alumina and iron and manganese oxides.	Lime carbonate.	Magnesia.	Phosphoric acid $(P_2 O_5)$.	Potash, extracted by acids.	Sand and insoluble silicates.	Water expelled at 212° F.	Potash in the insoluble silicates.	Rock fragments, gravel, pebbles, or sand.
Virgin soil, Campbell Co.—No. 1329	7.615	12.185	0.990	0.520	0.483	0.726	75.590	5.075	2.731	0
Soil, 12 years in cultivation, Jessamine Co.—No. 665	9.745	15.500	3.570	1.290	.532	.569	69.070	6.775	. . . .	. . . .
Virgin soil, Mercer Co.—No. 681	10.365	13.126	1.995	1.234	.333	.762	72.035	4.500	. . . .	. . . .
Composition of very rich soil, so-called "Red Bud soil," on the Lower Devonian formation.										
Virgin soil, Madison Co.—No. 1127	15.450	9.395	1.295	.750	.252	.753	71.045	. . . .	. . . .	. . . .

TABLE E.

EXAMPLES OF COMPOSITION OF FOREIGN SOILS (*Traité des Terres Arables, par M. D. Gasparin: Paris*, 1877).

			Lime.							
Ancient volcanic soil, celebrated for its fertility ("*Pont-du-Château, Limagne d'Auvergne*"). . .	5.390	15.330	3.852	.762	.416	.280	66.89	. . . .	. .	16.00
Vineyard soil, Morges, Vaud (Switzerland). . .	2.151	8.022	2.652	1.247	*.093	.246	80.126	. . . .	. . . .	19.05

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* M. De Gasparin remarks that this is a "good average" of phosphoric acid.

TABLE F.

EXAMPLE OF THE CHANGE IN COMPOSITION CAUSED BY CULTIVATION OF SOILS.

	Organic and volatile matters.	Alumina and iron and manganese oxides.	Lime carbonate.	Magnesia.	Phosphoric acid (P2 O5).	Potash, extracted by acids.	Sand and insoluble silicates.	Water expelled at 212° F.	Potash in the insoluble silicates.	Rock fragments, gravel, pebbles, or sand.
Virgin soil, Campbell Co.—No. 1324	3.650	6.559	.130	.034	.145	.120	87.545	1.765	n. e.	. . . .
Old field soil, Campbell Co.—No. 1325, more than 40 years in cultivation.	2.555	6.490	.090	.496	.109	.052	89.335	1.550	n. e.	. . . .

REVIEW OF THE AVERAGES OF COMPOSITION OF THE KENTUCKY SOILS ON THE SEVERAL GEOLOGICAL FORMATIONS

1. *Alluvial Soils.*—Made up of the finer and richer materials of the uplands; present, generally, more than the average proportions of essential elements and conditions, except that in the Ohio Valley soils organic matters are somewhat below average in some. The Mississippi Valley soils contain more organic matters, clay, carbonate of lime, phosphoric acid, and magnesia than the Ohio river soils. These latter have more potash.

2. *Quaternary Soils.*—Have less than average organic matters and of phosphoric acid; enough alumina and iron oxide, lime and magnesia, and average potash.

3. *The Coal Measures Soils.*—Present, generally, an average composition, to be discounted by variable quantities of fragments of rock or gravel.

4. *The Conglomerate Soils.*—Contain less than the average of all the essential elements; more than the average of sand and insoluble silicates, and are to be discounted by variable proportions of pebbles, gravel, &c. Yet no soil is so poor that it may not be made productive by the judicious use of fertilizers, if it has sufficient drainage.

5. *The Upper Sub carboniferous Soils.*—Contain less than the average of organic matters, but in other respects present nearly an average composition.

6. *The Lower Sub-carboniferous Soils.*—Contain nearly average proportions, except that their carbonate of lime and potash are somewhat below, and their sand and insoluble silicates exceed slightly. Gravel in variable, generally small, proportions, is sometimes present.

7. *Waverly Soils.*—Contain less than average alumina and iron oxide, phosphoric acid and carbonate of lime, magnesia and potash, and more than average sand and insoluble silicates.

8. *Black Slate Soils.*—Contain more than average proportions of organic matters, alumina and iron oxide, lime, magnesia, and phosphoric acid, and less than average potash, and sand and insoluble silicates, but sometimes need drainage.

9. *Corniferous Limestone Soils.*—Have more than average organic matters, alumina and iron oxide, lime, magnesia, phosphoric acid, and potash, and less than average sand and silicates.

10. *Upper Silurian Soils.*—Contain more than average proportions of nearly all the essential ingredients, and less than average potash, and sand and silicates.

11. *Silicious Mudstone* (*Middle Hudson*) *Soils.*—Contain average organic matters, alumina and iron oxide and phosphoric acid; more than average magnesia, and sand and insoluble silicates, and less than the average of carbonate of lime and potash.

12. *Blue Limestone* (*Trenton*) *Soils.* — Contain much more than average proportions of all the essential elements; less than average sand and insoluble silicates. The richest of all the soils.

13. *Birdseye Limestone Soils.* — Average organic matters, alumina and iron oxide; more than the average lime, magnesia, phosphoric acid, and sand and insoluble silicates, and less than average potash.

By reference to Tables C, D, and E, the comparison may easily be made of the relative composition of known rich and poor soils.

By Table E we may compare our Kentucky soils with celebrated European soils, as reported by one of the most experienced agricultural chemists.

Table F gives one of the many examples which might be quoted of the changes of chemical composition of the soil which results from long cultivation without manures.

That the reader may appreciate the significance of the percentage given in these tables, the writer will state that, by actual measurement and weighing of some of the rich soil of the Blue Grass Region, he found a cubic foot, in its ordinary condition, to weigh 71.543 pounds. Calculated to the depth of one foot, the soil on an acre would weigh 3,116,413 pounds. Other soils, especially poor, sandy soils, weigh much more than this.

When we calculate into this quantity of soil the 0.404 per cent. of potash, which appears as the average quantity in 32 Blue Grass soils, we find that it amounts to more than twelve thousand five hundred and ninety (12,590) pounds to the acre. On the other hand, taking the small proportion contained in the Old Field soil (Table F), only .062 per cent., the quantity in the acre to the depth of one foot is only one thousand nine hundred and thirty-two (1,932) pounds.

NOTE.—In the early period of the Geological Survey of Kentucky, the late Dr. D. D. Owen gave special attention to the study of the changes in composition, produced in the soil by cultivation without manures, and consequently collected, for comparative chemical analysis, many samples of *Virgin Soil* with that of an immediately neighboring field which had been long in cultivation. Of the one hundred and seventy-three soil analyses made by the writer up to 1860 (see *Vol. IV. O. S. Repts. Ky. Geol. Surv.*, p. 42), this comparison was made in seventy-nine cases ; and in seventy-one cases the soil of the old field, as compared with the virgin soil, had lost notable quantities of its essential elements of plant food.

TABLE G.

COMPOSITION OF LIMESTONES OF THE VARIOUS GEOLOGICAL FORMATIONS (DRIED AT 212° F.)

	Specific gravity.	Lime carbonate.	Magnesia carbon-ate.	Alumina and iron and manganese oxides.	Phosphoric acid (P_2O_5).	Sulphuric acid (SO_3).	Potash.	Soda.	Silica and sili-cates.	Iron carbonate.
COAL-MEASURES LIMESTONES.										
Carter Co. Vol. I, N. S., p. 192—No. 1390	n. e.	75.750	0.575	6.403	0.057	0.775	n. e.	n. e.	14.700	. . . .
Greenup Co. Vol. I, N. S., p. 241—No. 1498	n. e.	88.410	.797	3.760	.178	.044	.269	.240	5.960	. . . .
Greenup Co. Vol. I, N. S., p. 241—No. 1501	2.770	60.750	25.656	4.167	.013	.315	n. e.	. . . .	5.680	3.420
Henderson Co. Vol. 4, O. S., p. 182—No. 1046	2.777	88.380	3.678	1.760	.246	.166	.289	.068	3.280	. . . .
Muhlenburg Co. Vol. 3, O. S., p. 337—No. 705	n. e.	82.880	4.196	4.333	.247	*4.717	.135	.150	4.260	. . . .
Ohio Co. Vol. V, N. S., p. 229—No. 2073 (*Hydraulic?*)	n. e.	41.680	22.748	8.640	.153	n. e.	1.253	.323	24.060	. . . .
Average composition of the 6 Coal-measures Limestones	2.773	72.958	9.608	4.883	.152	1.003	.486	.195	9.657	. . . .
Average composition of the 2 Magnesian Limestones	. . . .	51.215	24.202	6.403	.083	.315	. . .	. . .	14.870	. . . .
Average composition of the 4 others	. . . .	83.605	2.312	4.064	.206	1.425	.231	.153	6.550	. . . .
UPPER SUB-CARBONIFEROUS LIMESTONES.										
Barren Co. Vol. I, N. S., p. 152—No. 1421 (*Oölitic*)	2.678	98.050	.363	.511	.051	.260	.115	.327	1.060	. . . .

* Equal to 1.891 p. c. of *sulphur*, in the form of yellow pyrites in the limestone.

TABLE G.—COMPOSITION OF LIMESTONES OF THE VARIOUS GEOLOGICAL FORMATIONS—Continued.

	Specific gravity.	Lime carbonate.	Magnesia carbonate.	Alumina and iron and manganese oxides.	Phosphoric acid (P2 O5).	Sulphuric acid (SO3).	Potash.	Soda.	Silica and silicates.	Iron carbonate.
UPPER SUB-CARBONIFEROUS LIMESTONES—Cont'd.										
Barren Co. Vol. I, N. S., p. 152—No. 1422 (*Compact*)	2.721	77.550	13.314	2.680	0.051	0.192	0.154	0.188	6.060	. . . .
Barren Co. Vol. I, N. S., p. 153—No. 1423 (*Lithographic*)	2.689	82.960	7.655	2.680	.115	.260	.135	.156	6.160	. . . .
Butler Co. Vol. I, N. S., p. 169—No. 1314	n. e.	93.020	2.088	.917	.243	.604	n. e.	n. e.	2.700	. . . .
Carter Co. Vol. I, N. S., p. 193—No. 1389	2.700	95.150	.245	1.390	.130	tr.	n. e.	n. e.	3.060	. . . .
Grayson Co. Vol. 4, O. S., p. 159—No. 992	n. e.	85.680	2.503	2.560	.182	.839	.359	tr.	7.480	. . . .
Greenup Co. Vol. I, N. S., p. 241—No. 1499	2.680	88.150	.385	.152	.051	n. e.	n. e.	n. e.	9.560	. . . .
Greenup Co. Vol. I, N. S., p. 241—No. 1500	2.700	92.050	.220	1.490	.128	.199	n. e.	n. e.	4.460	. . . .
Hardin Co. Vol. I, N. S., p. 178—No. 1037 (*Lithographic?*)	n. e.	79.180	11.469	.880	.156	.338	.173	.098	6.980	. . . .
Hardin Co. Vol. I, N. S., p. 178—No. 1039 (*Oölitic*)	n. e.	98.580	.629	.460	.125	.274	.154	.022	.380	. . . .
Average composition of the 10 Upper Sub-carboniferous Limestones	2.694	89.014	3.887	1.292	.123	.371	.181	.132	4.796	. . . .
LOWER SUB-CARBONIFEROUS LIMESTONES.										
Bath Co. Vol. 4, O. S., p. 68—No. 796 (*Hydraulic?*)	2.704	53.240	18.531	9.020	.117	.633	.444	.212	17.540	. . . .
Crittenden Co. Vol. 4, O. S., p. 123—No. 897 (*Hydraulic?*)	2.719	52.880	25.858	1.460	.098	.003	.394	.255	18.880	. . . .
Crittenden Co. Vol. 4, O. S., p. 123—No. 898 (*Hydraulic?*)	2.723	55.280	29.246	1.323	.117	tr.	.344	.056	14.280	. . . .
Average composition of the 3 Lower Sub-carboniferous Limestones	2.715	53.800	24.541	3.601	.111	.218	.394	.141	16.900	. . . .

BLACK SLATE LIMESTONES.										
Bullitt Co. Vol. 2, O. S., p. 141—No. 490 . . .	2.766	63.130	27.760	4.340	.190	*3.770	.440	.150	1.630	. . . .
Madison Co. Vol. 4, O. S., p. 119—No. 888 (*Hydraulic?*)	n. e.	40.280	15.903	9.460	n. e.	1.025	.436	.164	23.180	. . . .
Madison Co. Vol. 4, O. S., p. 212—No. 1123 (*Hydraulic?*)	2.691	49.320	30.729	2.960	.271	.509	.374	.056	14.180	. . . .
Nelson Co. Vol. 3, O. S., p. 343—No. 711 . . .	n. e.	51.660	32.000	5.550	n. e.	.090	.770	.460	9.780	. . . .
Average composition of the 4 Black Slate Limestones	2.728	51.097	26.258	5.578	.230	1.469	.505	.207	12.092	. . . .
CORNIFEROUS LIMESTONES.										
Madison Co. Vol. V, N. S., p. 451—No. 2199									Bitumin	ous.
(*probably hydraulic*)	n. e.	36.580	18.541	5.550		n. e.	n. e.	n. e.	31.990	. . . .
Madison Co. Vol. V, N. S., p. 451—No. 2200 (*probably hydraulic*)	n. e.	47.580	17.135	10.580		n. e.	n. e.	n. e.	18.190	. . . .
Average of the 2 (probably hydraulic) Limestones	. . . .	42.080	17.838	8.065		n. e.	n. e.	n. e.	25.090	. . . .
Jefferson Co. Vol. 4, O. S., p. 195—No. 1077 (*probably Upper Silurian or Niagara*)	n. e.	89.060	6.783	1.480	.310	.475	.154	.163	2.680	. . . .
Jefferson Co. Vol. 4, O. S., p. 195—No. 1078 (*probably Upper Silurian or Niagara*)	n. e.	92.560	4.615	.480	trace.	.166	.166	.070	2.580	. . . .
Average of the 2 Limestones	. .	90.810	5.699	.980	.155	.320	.160	.116	2.630	. . . .
UPPER SILURIAN (NIAGARA GROUP) LIMESTONES.										
(*a.*) *Magnesia Carbonate above 20 p. c.*										
Bullitt Co. Vol. 4, O. S., p. 105—Nos. 856, 857 (average of 2 samples).	n. e.	51.930	17.662	2.170	trace.	n. e.	.366	.212	6.183	. . . .
Estill Co. Vol. 4, O. S., p. 140—No. 947 (*probably hydraulic*)	n. e.	41.380	30.019	3.546	.374	1.471	.482	.019	18.680	4.321
Garrard Co. Vol. 4, O. S., p. 156—No. 985 (*probaly hydraulic*)	n. e.	34.780	21.470	5.200	.310	.956	.471	.130	35.180	. . . .

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* Contains iron pyrites equal 1.51 *sulphur*.

TABLE G.—COMPOSITION OF LIMESTONES OF THE VARIOUS GEOLOGICAL FORMATIONS—Continued.

	Specific gravity.	Lime carbonate.	Magnesia carbonate.	Alumina and iron and manganese oxides.	Phosphoric acid (P_2O_5).	Sulphuric acid (SO_3).	Potash.	Soda.	Silica and silicates.	Iron carbonate.
UPPER SILURIAN LIMESTONES—Continued.										
(*a.*) *Magnesia Carbonate above* 20 *p. c.*										
Madison Co. Vol. V, N. S., p. 449—Nos. 2193-4-5 (average of 3 samples)	n. e.	50.667	24.399	13.398	n. e.	n. e.	0.279	0.064	4.007	. . . .
Nelson Co. Vol. 4, O. S., p. 231—No. 1166 (*a*) (*probably hydraulic*)	n. e.	49.780	34.456	3.000	.246	.475	.270	.006	10.780	. . . .
Nelson Co. Vol. 4, O. S., p. 231—No. 1167 (*probably hydraulic*)	n. e.	50.480	38.154	2.100	.118	.289	.258	.260	8.380	. . . .
Average of the 9 Magnesian Limestones	n. e.	48.132	25.847	6.541	.175	.797	.339	.115	10.817	. . . .
(*b.*) *Magnesia Carbonate below* 20 *p. c.*										
Jefferson Co. Vol. 4, O. S., p. 195—average of 5 samples, Nos. 1077, 1078, 1079, 1080, & 1081	n. e.	87.780	7.096	.726	.386	.358	.140	.141	3.480	. . . .
CLINTON GROUP LIMESTONES.										
Bath Co. Vol. 4, O. S., p. 68—No. 796 (*probably hydraulic*)	n. e.	53.240	18.531	9.020	.117	.633	.444	.212	17.540	. . . .
Bath Co. Vol. 4, O. S., p. 68—No. 797	n. e.	51.580	28.779	11.408	.592	.235	.209	trace.	1.980	3.095
Fleming Co. Vol. 4, O. S., p. 151—No. 973 (*probably hydraulic*)	n. e.	42.680	25.358	12.434	.848	.324	.290	.033	10.880	5.155
Average of the 3 Clinton Limestones	n. e.	49.167	24.233	10.954	.519	.364	.314	.122	12.467	. . . .

UPPER HUDSON GROUP LIMESTONES.										
Mason Co. Vol. 4, O. S., p. 217—No. 1131 . . .	n. e.	75.440	4.783	3.751	.409	.474	.540	.292	14.440	. . . .
Mason Co. Vol. 4, O. S., p. 217—No. 1132 . . .	n. e.	87.980	1.721	2.200	.348	.372	.289	.047	6.380	. . . .
Mason Co. Vol. 4, O. S., p. 217—No. 1133. . .	n. e.	77.360	2.307	3.910	.310	*2.433	.424	.068	13.980	. . . .
Average of the 3 Upper Hudson Limestones. .	n. e.	8[illegible]260	2.934	3.287	.356	1.093	.418	.139	11.600	. . . .
MIDDLE HUDSON GROUP (*Silicious Mudstone of Dr. Owen.*)										
Bracken Co. Vol. III, N. S., p. 166—No. 1307 .	n. e.	.500	.345	14.959	.486	n. e.	2.735	1.515	76.060	. . . .
Bracken Co. Vol. 4, O. S., p. 83—No. 824 . . .	n. e.	.920	1.887	6.460	.438	.200	.560	.166	88.580	. . . .
Fayette Co. Vol. 2, O. S., p. 164—No. 505 . . .	n. e.	trace.	1.410	8.650	.250	.220	.270	.140	87.830	. . . .
Fayette Co. Vol. 2, O. S., p. 164—No. 506 . . .	n. e.	1.790	2.300	10.250	.500	.920	.410	.010	83.450	. . . .
Grant Co. Vol. 3, O. S., p. 276—No. 631 . . .	n. e.	.563	1.608	6.202	.378	.117	.363	.200	89.620	. . . .
Nicholas Co. Vol. 3, O. S., p. 360—No. 731 . .	n. e.	.743	.676	8.850	.572	.100	.473	.233	88.440	. . . .
Scott Co. Vol. 4, O. S., p. 254—No. 1225. .	n. e.	3.784	3.401	9.140	.566	.303	.579	.047	77.840	. . .
Average of the 7 "Silicious Mudstones"	n. e.	1.185	1.661	9.216	.456	.265	.413	.330	84.545	. . . .
LOWER HUDSON GROUP LIMESTONES.										
Anderson Co. Vol. 2, O. S., p. 132—Nos. 485-6 (average of 2 samples)	n. e.	85.200	1.240	2.030	.185	.170	.500	.290	10.425	. . . .
Bourbon Co. Vol. 3, O. S., p. 223—Nos. 578-9 (average of 2 samples).	n. e.	96.510	1.049	.542	.138	.180	.075	.174	1.886	. . . .
Franklin Co. Vol. 2, O. S., p. 173—No. 516 . .	n. e.	92.650	1.540	1.190	.090	1.270	.300	.130	3.680	. . . .
~~Mercer Co. Vol. 3, O. S., p. 325 No. 685~~ . .	n. e.	88.900	1.468	2.340	.631	.235	.168	.053	7.185	. . . .
Nicholas Co. Vol. 3, O. S., p. 361—No. 732 .	n. e.	78.680	1.566	2.480	.247	.270	.173	.172	16.640	. . . .
Owen Co. Vol. 3, O. S., p. 376—No. 742. . .	n. e.	92.920	.559	3.580	.349	.338	.162	.160	1.720	. . . .
Woodford Co. Vol. 2, O. S., p. 280—No. 549. .	n. e.	96.240	.945	1.040	.630	.178	.480	.390	.780	. . .
Average of the 9 Lower Hudson Limestones . .	. . . .	90.312	1.563	1.753	.288	.332	.270	.203	6.070	. . . .
TRENTON GROUP LIMESTONES.										
(*a.*) *Magnesia Carbonate below 5 p. c.*										
Clark Co. Vol. 4, O. S., p. 114—No. 876. . . .	2.735	85.560	3.567	3.280	.118	.474	.422	.462	5.920	. . . .
Fayette Co. Vol. 4, O. S., p. 149—No. 970 . . .	n. e.	91.480	1.044	3.980	.848	.317	.232	.336	2.380	. . . .

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* Derived from iron pyrites in the limestone.

TABLE G.–COMPOSITION OF LIMESTONES OF THE VARIOUS GEOLOGICAL FORMATIONS–Continued.

	Specific gravity.	Lime carbonate.	Magnesia carbonate.	Alumina and iron and manganese oxides.	Phosphoric acid (P2 O5).	Sulphuric acid (SO3).	Potash.	Soda.	Silica and silicates.	Iron carbonate.
TRENTON GROUP LIMESTONES—Continued.										
(*a.*) *Magnesia Carbonate below 5 p. c.*										
Fayette Co. Vol. 2, O. S., p. 165—No. 507 . . .	2.660	92.730	0.630	2.420	0.860	0.340	0.230	0.280	2.180	. . . .
Franklin Co. Vol. 3, O. S., p. 258—No. 615 . .	n. e.	95.380	1.510	.769	.311	.579	.108	.033	2.080	. . . .
Franklin Co. Vol. 2, O. S., p. 172—No. 514 . .	2.699	89.625	.880	.124	.440	.680	.230	.290	6.940	. . . .
Mercer Co. Vol. 4, O. S., p. 221—No. 1143 . .	n. e.	90.720	4.615	2.700	.146	n. e.	.328	.021	1.880	. . . .
Woodford Co. Vol. 2, O. S., p. 279—No. 547 . .	n. e.	91.330	.560	1.530	.700	.330	.340	.430	5.180	. . . .
Average of the 7 Limestones	2.698	90.976	1.828	2.155	.489	.453	.470	.265	3.794	. . . .
(*b.*) *Magnesia Carbonate above 5 p. c.*										
Bourbon Co. Vol. 4, O. S., p. 83—No. 822 . . .	n. e.	75.980	15.595	4.660	.822	.427	.165	.042	2.640	. . . .
Bourbon Co. Vol. I, N. S., p. 291—No. 1638 . .	2.600	71.140	11.826	5.890	.511	.240	.231	.252	2.270	. . . .
Fayette Co. Vol. 2, O. S. p. 165 No. 508	2.711	77.630	10.000	3.230	.700	3.120	.320	.150	4.980	. . . .
Fayette Co. Vol. 2, O. S., pp. 168-9 and 170—Nos. 511, 512, 513 (average of 3)	2.675	54.366	35.820	1.750	.310	.230	1.140	.430	5.917	. . . .
Fayette Co. Vol. 3, O. S., p. 259—No. 616 .	2.728	59.880	37.050	1.380	n. e.	n. e.	.610	.420	2.680	. . . .
Fayette Co. Vol. 4, O. S., p. 149—Nos. 967 and 969 (Ky. Marble, average of 2)	n. e.	70.070	19.252	3.670	.246	.303	.178	.272	4.130	. . . .
Franklin Co. Vol. V, N. S., p. 422—No. 2121 (*Hydraulic?*)	n. e.	70.360	6.784	6.800	n. e.	n. e.	1.118	.281	14.020	. . . .
Madison Co. Vol. 4, O. S., p. 212—No. 1123 (*Hydraulic?*)	2.691	49.320	30.729	2.960	.271	.509	.374	.058	14.180	. . . .
Average of the 11 Magnesian Limestones . . .	2.681	64.323	23.541	3.410	.414	.632	.590	.278	6.078	. . . .

BIRDSEYE LIMESTONES.										
Fayette Co. Vol. 4, O. S., p. 149—No. 968 . . .	n. e.	95.680	2.044	.380	.182	.166	.193	.048	1.580	. . . .
Woodford Co. Vol. 2, O. S., p. 280—No. 548 . .	2.705	94.750	1.960	.630	trace.	.300	.230	.032	2.180	. . . .
Average of the 2 Birdseye Limestones	. . . .	95.215	2.002	.505	.091	.233	.207	.040	1.880	. . . .
CHAZY LIMESTONES.										
Mercer Co. Laboratory Book, p. 1358 (No. 1) .	n. e.	62.860	30.720	1.220	n. e.	n. e.	n. e.	n. e.	5.000	. . .
Mercer Co. Laboratory Book, p. 1359 (No. 2) .	n. e.	83.580	10.550	.980	n. e.	n. e.	n. e.	n. e.	5.560	. . . .
Woodford Co. Vol. 3, O. S., p. 409—No. 776 . .	2.655	59.860	36.640	.980	n. e.	.160	.400	.080	2.480	. . . .
Average of the 3 Chazy Limestones	. . . .	68.767	25.970	1.060	n. e.	n. e.	n. e.	n. e.	4.346	. . . .

TABLE H.

GENERAL AVERAGES OF THE COMPOSITION OF THE LIMESTONES OF THE SEVERAL GEOLOGICAL FORMATIONS

(*Including also the Middle Hudson or Silicious Mudstone of Dr. Owen*).

	Specific gravity.	Lime carbonate.	Magnesia carbonate.	Alumina and iron and manganese oxides.	Phosphoric acid (P2 O5).	Sulphuric acid (SO3).	Potash.	Soda.	Silica and silicates.
Average composition of 6 Coal-measures Limestones. . .	. . . .	72.958	9.608	4.883	0.152	1.003	0.486	0.195	9.657
Average composition of 2 of these, which are magnesian and probably *Hydraulic*	. . . .	51.215	24.202	6.403	.083	.315	n. e.	n. e.	14.870
Average composition of 4 of these, not unusually magnesian	2.773	83.605	2.312	4.064	.206	1.425	.118	.153	6.550
Average composition of 10 Upper Sub-carboniferous Limestones	2.694	89.014	3.887	1.292	.123	.371	.181	.132	4.796
Average composition of 3 Lower Sub-carboniferous Limestones (*Hydraulic?*).	2.715	53.800	24.541	3.601	.111	.218	.394	.141	16.900
Average composition of 6 Black Slate Limestones. . . .	2.728	51.097	26.258	5.578	.230	1.469	.505	.207	12.092
Average composition of 4 Corniferous Limestones—									
Of which 2 are magnesian (*Hydraulic?*)	n. e.	42.080	17.838	8.065		n. e.	n. e.	n. e.	25.090
And 2 are non-magnesian	n. e.	90.810	5.999	.980	.155	.320	.160	.116	2.630
Average composition of 14 Niagara Group (or Upper Silurian) Limestones	n. e.	62.292	19.150	4.321	.250	.640	.267	.123	8.196
Of which 9 contain more than 20 p. c. of magnesia carbonate, and are probably *Hydraulic*	n. e.	48.132	25.847	6.541	.175	.797	.339	.115	10.817
And 5 contain less than 20 p. c. of magnesia carbonate	n. e.	87.780	7.096	.726	.386	.358	.140	.141	3.480
Average composition of 3 Clinton Group Limestones . .	n. e.	49.167	24.233	10.954	.519	.364	.314	.122	12.467
Average composition of 3 Upper Hudson Group Limestones	n. e.	80.260	2.934	3.287	.356	1.093	.418	.139	11.600
Average composition of 7 Middle Hudson Group ("Silicious Mudstone")	n. e.	1.185	1.661	9.216	.456	.265	.413	.330	84.545
Average composition of 9 Lower Hudson Limestones . .	n. e.	90.312	1.163	1.753	.288	.332	.270	.203	6.070

Average composition of 7 Trenton Limestones (*non-magnesian*)	2.698	90.976	1.828	2.155	.489	.453	.470	.265	3.794
Average composition of 11 Trenton Limestones (*magnesian*)	2.681	64.323	23.541	3.410	.414	.632	.590	.278	6.078
Average composition of 2 Birdseye Limestones	...	95.215	2.002	.505	.091	.233	.207	.040	1.880
Average composition of 3 Chazy Limestones	....	68.767	25.970	1.060	n. e.	n. e.	n. e.	n. e.	4.346

TABLE I.

COMPARATIVE REVIEW OF THE COMPOSITION OF THE LIMESTONES (*excluding the Silicious Mudstone*).

RELATIVE PROPORTIONS OF LIME CARBONATE.

The largest Average Proportions are in—	Per cent.	*Medium Average Proportions in—*	Per cent.	*Smallest Average Proportions in—*	Per cent.
Birdseye Limestones	*95.215	Coal-measures Limestones (in general)	72.958	Lower Sub-carboniferous Limestones,	53.800
Trenton Limestones (non-magnesian),	90.976	Chazy Limestones	68.766	Black Slate Limestones	51.270
Corniferous Limestones (resembling Upper Silurian)	90.810	Trenton Limestones (magnesian)	64.323	Coal-measures Limestones (magnesian)	51.215
Lower Hudson Limestones	90.312	Niagara Limestones (in general)	62.292	Clinton Limestones (magnesian)	49.167
Upper Sub-carboniferous Limestones,	89.014			Niagara Limestones (magnesian)	48.132
Niagara Limestones (non-magnesian),	87.780			Corniferous Limestones (magnesian),	42.080
Coal-measures Limestones (non-magnesian)	83.605				
Upper Hudson Limestones	80.260				

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* The largest proportions of lime carbonate of all the limestones analyzed were found in the Oölitic limestone of the Upper Sub-carboniferous formation, two samples of which yielded, severally, 98.58 and 98.05 per cent.

TABLE I.—COMPARATIVE REVIEW OF THE COMPOSITION OF THE LIMESTONES—Continued.

Relative Proportions of Magnesia Carbonate.

The largest Average Proportions are in—		*Medium Average Proportions in—*		*Smallest Average Proportions in—*	
	Per cent.		Per cent.		Per cent.
Black Slate Limestones	26.258	Coal-measures Limestones (in general)	9.608	Upper Sub-carboniferous Limestones,	3.887
Chazy Limestones	25.970	Niagara Limestones (non-magnesian)	7.096	Upper Hudson Limestones	2.934
Niagara Limestones (magnesian)	25.847	Corniferous Limestones (non-magnesian)	5.999	Birdseye Limestones	1.828
Lower Sub-carboniferous Limestones,	24.541			Lower Hudson Limestones	1.163
Clinton Limestones	24.233			Middle Hudson Limestones	.970
Coal-measures Limestones (magnesian)	24.202				
Trenton Limestones (magnesian)	23.541				
Niagara Limestones (in general)	19.150				
Corniferous Limestones (magnesian),	17.838				

Relative Proportions of Alumina and Iron and Manganese Oxides.

Clinton Limestones	10.954	Niagara Limestones (general average)	4.321	Lower Hudson Limestones	1.886
Corniferous Limestones (magnesian),	8.065	Trenton Limestones (magnesian)	3.410	Upper Sub-carboniferous Limestones,	1.292
Niagara Limestones (magnesian)	6.541	Lower Sub-carboniferous Limestones,	3.601	Chazy Limestones	1.060
Coal-measures Limestones (magnesian)	6.403	Upper Hudson Limestones	3.287	Corniferous Limestones (non-magnesian)	.980
Black Slate Limestones	5.578	Trenton Limestones (non-magnesian)	2.155	Niagara Limestones (non-magnesian),	.726
Coal-measures Limestones (general average)	4.883			Birdseye Limestones	.505

TABLE I.—COMPARATIVE REVIEW OF THE COMPOSITION OF THE LIMESTONES—Continued.

RELATIVE PROPORTIONS OF PHOSPHORIC ACID (P2 O5).

The largest Average Proportions are in—	Per cent.	*Medium Average Proportions in—*	Per cent.	*Smallest Average Proportions in—*	Per cent.
Clinton Limestones	0.519	Coal-measures Limestones (non-magnesian)	0.206	Lower Sub-carboniferous Limestones,	0.111
*Trenton Limestones (magnesian)	.489	Niagara Limestones (magnesian)	.175	Birdseye Limestones	.091
Trenton Limestones (non-magnesian),	.414	Upper Sub-carboniferous Limestones,	.123	Chazy Limestones (a trace)	n. e.
Niagara Limestones (small magnesia)	.386				
Upper Hudson Limestones	.356				
Lower Hudson Limestones	.288				
Niagara Limestones (general average),	.250				
Black Slate Limestones	.230				

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* In the Trenton limestone, near Lexington, in several localities, irregular layers of highly phosphatic limestone are found. A number of samples analyzed by the writer gave from 5.69 to 21.86 per cent. of phosphoric acid ($P_2 O_5$). The proportion of this valuable ingredient varies greatly in the different beds of this formation, and the general average of it is no doubt greater than appears in these tables.

RELATIVE PROPORTIONS OF SULPHURIC ACID (SO3).

Black Slate Limestones	1.467	Trenton Limestones (non-magnesian)	.435	Corniferous Limestones (magnesian),	.320
Coal-measures Limestones (non-magnesian)	1.425	Upper Sub-carboniferous Limestones,	.371	Coal-measures Limestones (magnesian)	.315
Upper Hudson Limestones	1.093	Clinton Limestones	.364	Birdseye Limestones	.233
Coal-measures Limestones (general average)	1.003	Niagara Limestones (non-magnesian)	.358	Lower Sub-carboniferous Limestones,	.218
Niagara Limestones (magnesian)	.797	Lower Hudson Limestones	.332		
Niagara Limestones (general average),	.640				
Trenton Limestones (magnesian)	.632				

TABLE I.—COMPARATIVE REVIEW OF THE COMPOSITION OF THE LIMESTONES—Continued.

RELATIVE PROPORTIONS OF POTASH.

The largest Average Proportions are in—		*Medium Average Proportions in*		*Smallest Average Proportions in—*	
	Per cent.		Per cent.		Per cent.
Trenton Limestones (magnesian) . .	0.590	Birdseye Limestones	.207	Corniferous Limestones (non-magnesian)	0.160
Black Slate Limestones.	.505	Upper Sub-carboniferous Limestones,	.181	Niagara Limestones (non-magnesian),	.140
Coal-measures Limestones (general average).	.486			Coal-measures Limestones (non-magnesian)	.118
Trenton Limestones (non-magnesian),	.470				
Upper Hudson Limestones .	.418				
Lower Sub-carboniferous Limestones,	.394				
Niagara Limestones (magnesian) . .	.339				
Clinton Limestones	.314				
Lower Hudson Limestones	.270				
Niagara Limestones (general average),	.267				

RELATIVE PROPORTIONS OF SODA.

Middle Hudson Limestones.	.330	Coal-measures Limestones (non-magnesian). . .	.153	Niagara Limestones (general average)	.123
Trenton Limestones (magnesian) . .	.278	Lower Sub-carboniferous Limestones,	.141	Clinton Limestones	.122
Trenton Limestones (non-magnesian),	.265	Niagara Limestones (non-magnesian).	.139	Corniferous Limestones (non-magnesian) . . .	.116
Black Slate Limestones.	.207	Upper Sub-carboniferous Limestones,	.132	Niagara Limestones (non-magnesian),	.115
Lower Hudson Limestones	.203			Birdseye Limestones.	.040
Coal-measures Limestones (general average).	.195				

TABLE I.—COMPARATIVE REVIEW OF THE COMPOSITION OF THE LIMESTONES—Continued.

RELATIVE PROPORTIONS OF SILICA AND SILICATES.

The largest Average Proportions in—	Per cent.	*Medium Average Proportions in—*	Per cent.	*Smallest Average Proportions in—*	Per cent.
Corniferous Limestones (magnesian),	25.090	Coal-measures Limestones (general average)	9.657	Trenton Limestones (non-magnesian),	3.794
Coal-measures Limestones (magnesian, only 1 sample)	24.060	Niagara Limestones (general average)	8.196	Niagara Limestones (non-magnesian)	3.480
Lower Sub-carboniferous Limestones,	16.900	Coal-measures Limestones (non-magnesian)	6.550	Corniferous Limestones (non-magnesian)	2.630
Coal-measures Limestones (magnesian)	14.870	Trenton Limestones (magnesian)	6.078	Birdseye Limestones	1.880
Clinton Limestones	12.460	Lower Hudson Limestones	6.055		
Black Slate Limestones	12.092	Upper Sub-carboniferous Limestones,	4.796		
Upper Hudson Limestones	11.600	Chazy Limestones	4.336		
Niagara Limestones (magnesian)	10.817				

GENERAL REMARKS ON THE LIMESTONES OF KENTUCKY.

As may be seen in the appended tables of average chemical composition, these limestones present a great variety, and are applicable to numerous practical uses.

For building stones, the limestones of most of the formations may be employed, those especially which can be quarried of suitable size and form. The best and most durable are those which possess a close, compact or fine granular structure, without cracks or crevices, which consequently would not absorb much water, or be liable to be disintegrated by frost, and which do not contain much iron pyrites or iron protoxide, and are not full of fossils or chert. The most durable of all the limestones hitherto tried are the compact homogeneous layers of the pure magnesian limestone of the Lower Silurian group, of fine granular structure, such as was used in the Clay monument in the cemetery at Lexington. Some of the beds of the Birdseye Limestone are compact enough to receive a good polish, and to take the name of marble. The Lower and Upper Silurian groups, including Lower and Upper Hudson, the Corniferous and Upper Sub-carboniferous groups, as well as some beds of Coal-measures limestones, &c., all include layers sufficiently pure and homogeneous and of proper structure to answer well for building purposes.

The oölitic layers of the Upper Sub-carboniferous formation are remarkably pure carbonate of lime, containing more than 98 per cent. of that material.. It would, by calcination, yield a very pure, white lime, which might be utilized in many manufacturing processes. Pulverized, it would prove available in the manufacture of glucose, for neutralizing the sulphuric acid employed, especially as it contains but little magnesia. Some of the layers take a good polish. The Birdseye limestone is also quite pure, and would yield a very white lime. Some of its layers are susceptible of a good polish, and have been used and known as "Kentucky marble." It is quite compact, but somewhat brittle.

Some of the layers of this Sub-carboniferous limestone are available for lithographic purposes. These have been found and quarried in Menifee, Barren, Hardin, Estill, and Meade counties. Their availability for this purpose depends mainly on their fine granular structure, their freedom from fossils, flaws, cracks, or irregularities of texture, and the possibility of obtaining slabs of good size of a homogeneous character. Those which have been analyzed contained a considerable percentage of magnesia carbonate.

All of these limestones could be utilized in the preparation of mortars and cements. Of course those which are the purest would slack the hottest, and give what is technically called "fat lime," and would probably harden in the air more firmly, when mixed with a proper proportion of clean, sharp silicious sand, than the less pure lime, and hence would be preferred by the bricklayer and plasterer, and for preparing the whitest wash; but any of the ordinary limestones of the several geological formations may be used for building purposes, and experience has shown that some of them which contain considerable proportions of silica and silicates, alumina, iron oxide, and magnesia, although their lime may not slack so readily or so hot as that of the purer limestones, yet will resist the action of water and of other atmospheric agencies better than some of those which are purer carbonate of lime.

For *cements*, or mortars which are used to withstand the action of water, so-called *hydraulic or water cements*, what we may call *impure limestones* are generally available. The hydraulic or water limestones frequently contain a considerable proportion of magnesia. Indeed, some quick-setting water limes seem to owe their peculiar property to the admixture of magnesia; but the cement of such limestones is said not to be so durable or so perfectly water-proof as that containing considerable proportions of silica and of alumina and iron oxide. "A very striking proof of the influence of magnesia * * * is afforded by the limestone from Tarnowitz, * * * which hardens extremely well, although it only contains 3.35 per cent. of silica. This limestone contains 29.32

per cent. of carbonate of magnesia." It contains 16.83 per cent. of carbonate of iron, 3.75 of alumina, and 49.06 per cent. of carbonate of lime. (*Knapp's Chem. Technology, vol. 1, pp.* 378, 385.) Proportions of potash and soda not given. By reference to our tables of average compositions this will be seen to resemble some of our Kentucky limestones.

The statement of the composition of the celebrated hydraulic limestone from the neighborhood of the Falls of the Ohio river at Louisville, Jefferson county (*see vol.* 2, *O. S., Ky. Geol. Repts., p.* 220), may be given as the type of that of a good hydraulic limestone, dried at 212° F., as follows:

	Per cent.	
Carbonate of lime	50 43	= 28.29 per cent. of lime.
Carbonate of magnesia	18 67	= 8.89 per cent. of magnesia.
Alumina and iron and manganese oxides	2.93	
Phosphoric acid (P_2O_5)	.06	
Sulphuric acid (SO_3)	1.58	
Potash	.32	
Soda	.13	
Sand and insoluble silicates	25.78	Containing silica = 22.58 per cent.
Loss	.10	
	100.00	

The reader is referred to vol. IV, N. S., of Ky. Geol. Repts., pp. 404 to 408, for more full statements and remarks in relation to hydraulic limestones and cements. According to the experiments and analyses of Berthier and Kersten, 5 to 9 per cent. of silica, alumina, and iron carbonate, with from 0.40 to 5 per cent. of magnesia carbonate in the composition of a limestone, give to it a very moderate hydraulic character, while 13 per cent. of these ingredients, with 4 per cent. of magnesia carbonate, give it marked hydraulic properties. (*Knapp's Chem. Tech., v.* 2, *p.* 379). But, as stated in vol. IV, N. S., of Ky. Geol. Repts., above referred to, the presence of the alkalies, potash, and soda no doubt is an important factor in the composition of a hydraulic limestone.

Limestone, calcined and air-slacked, or simply ground up without calcination, is employed in some localities to improve the quality of the soil, and increase its fertility. It may operate in a variety of modes. Its constant action is to neutralize acids, and to decompose sulphate of iron and some forms of organic matters, aiding in the formation of ammonia, and favoring nitrification under some circumstances, thus assisting in supplying available nitrogen to crops. Applied in large quantities, as slacked lime, it greatly improves the texture of heavy, tenacious clay soils, rendering them more friable and penetrable by fluids. No doubt, while in the caustic state, slacked lime acts somewhat on the insoluble silicates of the soil, and sets free some of the alkalies and other valuable ingredients. But it is highly probable that the most profitable lime for use as a fertilizer would be that which had in its composition the largest proportions of potash, phosphoric acid, sulphuric acid, soda, &c. These valuable elements of plant food are in largest proportions in the impure limestones, and would be more quickly available in the calcined lime than in the ground limestone. It appears to have become somewhat fashionable to apply ground limestone to the soil as a fertilizer, but unless a limestone very rich in phosphoric acid and potash is selected for this use, it is very questionable whether it would be profitable on any but a soil which was very deficient of lime. The practice of adding ground limestone to commercial fertilizers would generally be profitable to the manufacturer only.

One very important use of limestone is as a flux in the smelting of iron ore. For this purpose a carbonate of lime containing little or no phosphoric acid or sulphuric acid or pyrites (iron sulphide) would be most appropriate. The presence of moderate quantities of silica and silicates, or of magnesia, potash, or soda, would not be objectionable. Indeed, the ferruginous limestones found in the coal-measures would increase the product of iron; and the oxide of manganese, which occurs sometimes in these limestones in notable proportions, would improve the quality of the fluxing material, as well as that of the iron produced.

TABLE J.

AVERAGES OF THE COMPOSITION OF THE CLAYS OF THE SEVERAL GEOLOGICAL FORMATIONS OF KENTUCKY.

(*Dried at 212° F.*)

	Silica, &c.	Alumina	Iron peroxide.	Lime.	Magnesia.	Phosphoric acid.	Potash.	Soda.	Water and loss.	Fine sand.
TERTIARY CLAYS (*Dried at 212° F.*) (1.) FIRE-CLAYS.										
Ballard Co. Vol. V, N. S., p. 411—No. 2104 (*a*),	74.460	18.070	1.633	.314	.245	n. e.	.940	.021	4.317	48.000
Ballard Co. Vol. V, N. S., p. 411—No. 2105 (*a*),	67.501	23.051	2.109	.257	.065	n. e.	.412	.020	6.585	54.000
Fulton Co. Vol. I, N. S., p. 217—No. 1439 (*a*) .	74.960	18.350		.304	.309	.051	.230	.124	5.800	n. e.
Fulton Co. Vol. I, N. S., p. 217—No. 1440 (*a*) .	81.060	13.609		.314	.139	.051	.231	.021	3.600	n. e.
Fulton Co. Vol. V, N. S., p. 430—Nos. 2136 to 2141, inclusive (average of 4 clays) (*a*). . . .	79.735	12.542	2.427	.453	.178	n. e.	.628	.122	3.914	n. e.
Graves Co. Vol. V, N. S., p. 433—No. 2143 (*a*),	*75.555	16.751	1.198	trace.	.144	n. e.	1.094	.216	5.047	*63.000
Hickman Co. Vol. V., N. S., p. 442—No. 2162 (*a*),	*84.918	10.560	1.102	.572	.108	n. e.	.651	n. e.	2.089	*68.500
Average composition of the 10 Tertiary fire-clays,	77.739	14.825	1.969	.358	.172	n. e.	.607	.099	4.309	n. e.
(2.) POTTER'S CLAYS.										
Fulton Co. Vol. V, N. S., p. 430—Nos. 2134-2139, inclusive (average of 4 clays) (*a*). . . .	71.021	17.977	3.417	1.019	.262	n. e.	.721	.229	5.276	n. e.
Hickman Co. Vol. V, N. S., p. 442—No. 2163 (*a*),	76.360	14.951	2.109	.325	.173	n. e.	1.171	.125	4.786	n. e.
Average composition of the 5 Tertiary Potter's Clays	72.088	17.372	3.212	.880	.228	n. e.	.814	.208	5.218	n. e.
COAL-MEASURES CLAYS. (1.) FIRE-CLAYS.										
Carter Co. Vol. I, N. S., p. 179—Nos. 1337-8-9 (average of 3), most refractory (*a*).	49.713	36.156	traces.	.086	traces.	.354	.250	.434	13.007	n. e.

Carter Co. Vol. I, N. S., p. 179—Nos. 1340-1-2 (average of 3), less refractory (*a*)	57.427	31.861	trace.	.228	.070	.466	1.188	.609	8.193	n. e.
Greenup Co. Vol. 1, O. S., p. 332—Nos. 124-5 (average of 2), (*a*)	58.740	30.000	n. e.	.067	.073	n. e.	.072	.225	8.915	n. e.
Greenup Co. Vol. I, N. S., p. 236—Nos. 1477-81-83 (average of 3), most refractory (*a*)	54.780	32.678	trace.	.198	.306	.464	.551	.296	10.532	n. e.
Greenup Co. Vol. I, N. S. p. 236—Nos. 1478-79-82 (average of 3), less refractory (*a*)	61.680	24.814	1.270	.232	1.069	.431	1.905	.636	7.934	n. e.
Greenup Co. Vol. I, N. S., p. 236—No. 1480, least refractory (*a*)	47.060	36.620	trace.	.615	.389	.626	1.156	.234	13.300	n. e.
Ohio Co. Vol. V, N. S., p. 230—No. 2076 (*a*)	62.760	24.420	1.580	.325	trace.	n. e.	.906	.268	7.731	5.300
Union Co. Vol. 1, O. S., p. 361—No. 167 (*b*)	73.000	17.600	3.000	.336	n. e.	n. e.	.100		5.700	n. e.
Average composition of the 17 Coal-measures fire-clays	57.159	30.304	1.280	.214	.286	.443	.537	.407	9.621	....
(2.) POTTER'S CLAYS.										
Butler Co. Vol. V, N. S., p. 187—No. 1995 (*a*)	51.660	15.560	7.680	7.269	.817	n. e.	3.276	.293	13.445	n. e.
Ohio Co. Vol. V, N. S., p. 230—Nos. 2074-5 (average of 2 clays) (*a*)	70.060	17.940	.382	trace.	.659	n. e.	2.726	.231	4.563	n. e.
Average composition of the 3 Coal-measures Potter's clays	63.927	17.147	2.815	2.423	.712	n. e.	2.909	.231	7.524	....
BLACK SLATE—POTTER'S CLAY.										
Madison Co. Vol. V, N. S., p. 445—No. 2168 (*a*),	62.560	24.780	1.800	trace.	0.317	n. e.	3.276	.294	6.973	....
CRAB ORCHARD SHALE (CLINTON?)—POTTER'S CLAY.										
Madison Co. Vol. V, N. S., p. 445—Nos. 2169, 2170 (average of the 2) (*a*)	63.573	21.550	3.980	.386	.533	n. e.	5.167	.308	4.655	....
MIDDLE HUDSON FORMATION.										
Boone Co. Vol. IV, N. S., p. 35—No. 1697 (*a*)	48.360	33.060		3.057	.367	n. e.	4.664	1.706	8.786	....

TABLE J.—AVERAGES OF THE COMPOSITION OF THE CLAYS OF THE SEVERAL GEOLOGICAL FORMATIONS OF KENTUCKY—Continued.

	Silica, &c	Alumina.	Iron peroxide.	Lime.	Magnesia.	Phosphoric acid.	Potash.	Soda.	Water and loss.	Fine sand.
GENERAL AVERAGES OF THE CLAYS (*Dried at* 212°).										
(1.) FIRE-CLAYS.										
General average composition of 10 Tertiary fire-clays (*a*)	77.739	14.825	1.969	.358	.172	n. e.	.607	.099	4.309	. . . .
General average composition of 17 Coal-measures fire-clays (*a*)	57.159	30.304	1.280	.214	.286	.443	.537	.407	9.621	. . . .
General average composition of the 27 fire-clays (*a*)	[illegible].449	22.564	1.624	.286	.229	. . . .	.572	.253	6.965	. . . .
(2.) POTTER'S CLAYS.										
General average of 5 Tertiary Potter's clays (*a*),	72.088	17.372	3.212	.880	.228	n. e.	.814	.208	5.218	. . . .
General average of 3 Coal-measures Potter's clays (*a*)	63.927	17.147	2.815	2.423	.712	n. e.	2.909	.231	7.524	. . . .
General average of 3 Black Slate and Clinton Potter's clays (*a*).	63.235	22.627	3.189	.257	.461	n. e.	4.537	.303	5.428	. . . .
Composition of 1 Middle Hudson Potter's clay (*a*)	48.360	33.060		3.057	.367	n. e.	4.660	1.706	8.786	. . . .
Average composition of the 12 Potter's clays (*a*).	65.857	22.809		1.292	.419	n. e.	2.588	.362	6.144	. . . .
Average proportion of the alumina and iron peroxide in 11 of these clays	. . . .	18.744	3.096	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .

For Comparison, the following Analyses of Foreign Fire-clays are Appended:										
Average composition of 3 German Glass pot clays (vol. IV, N. S., p. 163—Nos. II, I, and J),	71.686	21.320	1.560	.292	.293	n. e.	.549	.079	5.630	. . . .
Composition of Chinese porcelain clay (vol. I, N. S., p. 181) (*a*).	55.300	30.300	2.000	n. e.	.400	n. e.	1.100	2.700	8.200	. . . .
Composition of Stourbridge (England) fire-clay (vol. I, N. S., p. 181) (*a*). . .	63.400	31.700	3.000	n. e.	n. e.	n. e.	1.900		n. e.	. . . .

(*a*) Analyzed by fusion with alkaline carbonates, &c., &c.
(*b*) Analyzed by digestion in acids, &c.
* Fine sand included in the total silica.

COMPARATIVE REVIEW OF THE AVERAGE COMPOSITION OF THE CLAYS OF THE SEVERAL GEOLOGICAL FORMATIONS, &c.

(a.) Fire Clays.

Relative Proportions of Silica, &c.

The largest Average Proportions in—	Per cent.	Medium Proportions in—	Per cent	Smallest Proportions in—	Per cent.
Tertiary fire-clays	77.739	Stourbridge fire-clay (English) . . .	63.400	Coal-measures fire-clays.	57.159
German glass-pot clays.	71.686			Chinese porcelain clay.	55.300

Relative Proportions of Alumina.

Stourbridge fire-clay	31.700	German glass-pot clays	21.320	Tertiary fire-clays.	14.825
Coal-measures fire-clay.	30.304				
Chinese porcelain clay	30.300				

COMPARATIVE REVIEW OF THE AVERAGE COMPOSITION OF THE CLAYS OF THE SEVERAL GEOLOGICAL FORMATIONS, &c. Continued.

(*a.*) FIRE-CLAYS.

Relative Proportions of Iron Peroxide.

The largest Average Proportions in—	Per cent.	Medium Proportions in –	Per cent.	Smallest Proportions in—	Per cent.
Stourbridge fire-clay	3.000	Tertiary fire-clay	1.969	Coal-measures fire-clays	1.280
Chinese porcelain clay	2.000	German glass-pot clay.	1.560		

Relative Proportions of Lime.

Tertiary fire-clays	.385	German glass-pot clays	.292	Coal-measures fire-clays	.214

Relative Proportions of Magnesia.

Chinese porcelain clay	.400	German glass-pot clays	.293	Tertiary fire-clays.	.172
		Coal-measures fire-clays	.286		

Relative Proportions of Potash.

Chinese porcelain clay	1.100	Tertiary fire-clays.	.607	Coal-measures fire-clays	.537
		German glass-pot clays	.549		

Relative Proportions of Soda.

The largest Average Proportions in—		Medium Average Proportions in—		Smallest Average Proportions in—	
	Per cent.		Per cent.		Per cent.
Chinese porcelain clay	2.700	Coal-measures fire-clays	0.407	Tertiary fire-clays	0.099
				German glass-pot clays	.079

(b.) POTTER'S CLAYS.

Relative Proportions of Silica, &c.

Tertiary clays	72.088	Coal-measures clays	63.927	Middle Hudson clays	48.360
		Black Slate clays	63.235		

Relative Proportions of Alumina.

Black Slate clays	22.627			Tertiary clays	17.372
				Coal-measures clays	17.147

Relative Proportions of Iron Peroxide.

Tertiary clays	3.212	Coal-measures clays	2.815		
Black Slate clays	3.189				

COMPARATIVE REVIEW OF THE AVERAGE COMPOSITION OF THE CLAYS OF THE SEVERAL GEOLOGICAL FORMATIONS, &c.—Continued.

(b.) POTTER'S CLAYS.

Relative Proportions of Lime.

The largest Average Proportions in—		Medium Average Proportions in—		Smallest Average Proportions in—	
	Per cent.		Per cent.		Per cent.
Middle Hudson clays	3.057	Coal-measures clays	2.057	Tertiary clays	0.880
				Black Slate clays	.257

Relative Proportions of Magnesia.

The largest Average Proportions in—		Medium Average Proportions in—		Smallest Average Proportions in—	
Coal-measures clays	.712	Black Slate clays	.461	Tertiary clays	.228
		Middle Hudson clays	.367		

Relative Proportions of Potash.

The largest Average Proportions in—		Medium Average Proportions in—		Smallest Average Proportions in—	
Middle Hudson clays	4.660	Coal-measures clays	2.903	Tertiary clays	.814
Black Slate clay	4.537				

Relative Proportions of Soda.

The largest Average Proportions in—		Medium Average Proportions in—		Smallest Average Proportions in—	
Middle Hudson clays	1.706	Black Slate clays	.303	Coal-measures clays	.231
				Tertiary clays	.208

GENERAL REMARKS ON THE KENTUCKY FIRE-CLAYS.

It will be seen that the best and greatest quantities of our fire-clays hitherto observed are found in the Coal-measures and Tertiary formations. In the former they are usually in an indurated condition, requiring grinding or exposure to the atmospheric agencies to make them plastic. In the Tertiary beds they are more friable, and easily to be kneaded with water. This marked difference is greatly owing to difference in composition. The Tertiary clays contain much more silica and less alumina than those of the Coal-measures, and much of this silica is in the form of fine sand, as may be seen by reference to the foregoing tables. This causes the Tertiary clays to be less plastic and adhesive than those of the Coal-measures, but probably may cause them to be rather more refractory in the fire. The plastic clays or Potter's clays have not been examined in so large number as the fire-clays, but have a wider range in the several geological formations. All forms of clays have numerous industrial applications, varying from the most costly products of the ceramic art to the rude brick or draining tile.

INFLUENCE OF THE SEVERAL CHEMICAL INGREDIENTS OF CLAYS.

Pure hydrated aluminum silicate, which is the essential basis of all clays, has a composition represented by 46.3 per cent. of silica, 39.8 per cent. of alumina, and 13.9 per cent. of water. $= (Al_2 O_3, 2\ S.O_2, H_2O.)$ It is sometimes found in the mineral kingdom in varying conditions of purity. The mineral halloysite is of this nature, and the so-called Indianaite of Cox, having a composition represented by 45.90 per cent. of silica, 40.30 per cent. of alumina, 13.26 per cent. of water, with

0.198 per cent. of potash, 0.204 per cent. of soda, and traces of lime,* is of this character. In the pure state the silicate of alumina is highly refractory, being infusible before the blowpipe, and practically fire-proof. It shrinks so much on drying, and especially when calcined, and is hence so liable to crack in the fire, that it cannot be made practically useful as a fire-clay until mixed with a considerable proportion of pure fine sand or ground burnt fire-clay. The admixture of fine sand does not sensibly reduce its refractory character, provided it is pure and free from fluxing materials, such as iron or manganese oxides, lime or magnesia, or the alkalies potash and soda, each of which substances increases the fusibility of the clay in which they are present. According to the experiments of Richter, in 1868, "the refractory quality of clays are least impaired by magnesia, more by lime, yet more by iron oxide, and most by potash." It is probable that soda is at least as active in this respect as potash, and the oxide of manganese more so than the oxide of iron. The phosphates also increase the fusibility of the clay.

The admixture of pure sand diminishes the plasticity and also the contractility of the clay on being dried or calcined, and increases its porosity. The same object is attained by mixing it with ground burnt fire-clay, plumbago, or ground coke or anthracite, and these substances are believed not to diminish the refractory quality of the clay. The well known Hessian crucibles or sand crucibles are an example. The Hessian crucible clay is composed of 71 per cent. of silica, 25 per cent. of alumina, 4 per cent. of iron oxide,† mixed with one third to one half its weight of quartz sand. It is said, however, that the quartz sand increases the fusibility of the clay when it is heated with fluxing materials, especially with oxide of lead, and that the substitution of ground burnt clay, of a pure kind, for the quartz sand, makes the crucible more refractory.

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*See Ky. Geol. Repts., vol. IV, N. S., pp. 164–5.

†This quantity of oxide of iron no doubt decreased the refractory quality of the clay, but this influence is somewhat counteracted by the large proportion of silica in the clay, and by the sand. The proportions of lime and of the alkalies are not given; some are undoubtedly present in this clay.

The black lead crucible, so-called, made of clay mixed with plumbago, is less porous, and takes a smoother finish than the sand crucible, and is more durable and less liable to break; hence it is used in the fusion of the precious metals and steel. Fire-bricks, tiles for lining furnaces, &c., are also made of the most refractory clays, mixed with pure sand or ground burnt fire-clay.

For making the large crucibles or pots used for melting glass, in which process the material is not only exposed for a great length of time to a very high temperature in the furnace, but also to the influence of fluxes in the contained melted glass, clay of a peculiar character, called glass-pot clay, is largely imported into this country from Germany at a considerable expense, it having been somewhat purified in that country.

As may be seen in the foregoing tables, this clay, as compared with the general average composition of our fire-clays, contains more than the usual proportion of silica, viz: 71.686 per cent., including the fine sand, it being exceeded in this respect only by some of our Tertiary fire-clays, which contain 77.739 per cent. (In regard to this ingredient, silica or sand, something depends on its state of division or combination. In *combination* with the alumina it forms the tough, plastic basis of clay, but in the form of *sand*, the coarser it is the more it diminishes that toughness or plastic character. Sand, in a *very fine* powder, partakes of the plastic nature of clay on mixture with water.) This glass-pot clay contains only a medium proportion of alumina, viz: 21.30 per cent., and a comparatively small proportion of iron oxide, but more of this injurious ingredient than some of our Coal-measures fire-clays, and not much less than some of the Tertiary. It has, by comparison with our fire-clays, small quantities of lime, magnesia, and potash, resembling, in this respect, some of our Coal-measures and Tertiary clays; it also has only a very small proportion of soda.

In England they use their Stourbridge fire-clays for the preparation of their glass-pots, and the chemical composition of these, as given by Knapp (*Chem. Tech.*, *v.* 2, *p.* 35), from analyses by Richardson, is as follows.

Silica (including fine sand?) from	61.15 to 68.05	per cent.
Alumina from	18.18 to 25.00	"
Oxide of iron from.	1.10 to 5.10	"
Lime from.	0 to 1.30	"
Magnesia from.	n. e. .85	"
Water from	6.00 to 12.50	"

Alkalies, potash, and soda not given; probably as above = 1.90 per cent.

On examining the tables of the composition of our fire-clays, several may be seen which would most probably serve admirably for the construction of glass-pots, more especially if the same care be taken to prepare and purify them as is used in Europe.

In using clay for refractory pottery, fire-bricks, or tiles, &c., much depends on the preparation of the clay. It is laid up in heaps or ridges, fully exposed to the weather, for months. The water and oxygen of the atmosphere, and the influence of frost, disintegrates it and measurably washes and purifies it. By the combined influence of moisture, oxygen, and any organic matter which may be present, insoluble iron sulphides are converted into soluble sulphate, and insoluble iron peroxide changed to soluble iron bi-carbonate. Some of the lime and magnesia are also washed out by the rains as soluble bi-carbonates, and some of the residual potash and soda, which entered into the chemical constitution of the rocks from which the clays were originally derived by the process of prolonged weathering, will become separated by the same process, and washed out by water; and thus the clay becomes greatly improved in purity and in its refractory character. The washing part of the process is aided artificially, and thus also are the pebbles, fine or coarse sand, separated, more or less, as may be necessary, from the finer particles of the impalpable silicate of alumina. In the purification of some clays, the powdered and softened mass is mixed with impure water, containing organic matters, and allowed to ferment or rot in a warm atmosphere. The decomposing organic matters aid greatly in the separation of the mineral impurities, by bringing them into a soluble form, as detailed above, and thus facilitate their removal from the clay by subsequent washing with purer water, For crucibles, glass-pots, fire-bricks, and tiles, very refractory clays alone can be used, containing as large a proportion of silica in the form of sand, more or less fine, or of ground burnt clay, as can be used without destroying the plasticity and adhesiveness of the mass, and the smallest possible proportions of potash or soda, lime, oxide of iron, or magnesia. The most refractory clays burn white, because of their very small proportion of iron oxide, which, when exceeding one to two per cent., begins to give a yellowish tint to the burnt clay, increasing in intensity and passing into various shades of orange, red, and brown, as the quantity increases, and proportionately increasing its fusibility. The best fire-clays should not contain more than from 0.2 to 0.5 per cent. of either lime, potash, soda, or magnesia; their fusibility increases as the proportions of these fluxing materials increase. For many of the ordinary uses of these clays, however, these proportions may be double, or treble in some cases, without detriment, where the heat to be resisted is not very intense.

But for the numerous uses of the potter, in the manufacture of the various products of the ceramic art; from the pure and highly artistic, richly decorated porcelain, the parian, wedgwood, stone-ware, delf, queen's-ware, majolica so called, down to the simple red flower-crock or the common brick, clays less refractory and less pure are available. Even many of the marls, or marly clays, which would melt into a slag at a bright heat, or become deep colored, red or brownish-red by calcination, because of their large proportions of fluxing materials, including iron oxide, are employed; and it is a remarkable fact, demonstrated in the most ancient remains of human art, that whatever may have been the kind employed, articles made of clay, if they have been well burnt or calcined without fusion, withstand the influence of time and the atmospheric agencies better than any other building material known; while ancient granite, porphyry, and marbles, are found to be corroded more or less, the clay tablets of the most ancient peoples are measurably unchanged.

The pure white porcelain or china-ware is only to be made of the primary clay called kaolin, derived from the decomposition of white felspar, mixed with a proper quantity of pure powdered quartz and undecomposed felspar, with sometimes a certain quantity of fluxing material, which causes it to soften somewhat or frit in the heat of the kiln. This softening or fritting, caused by the presence in the clay of lime, the alkalies, or other fluxing materials, also gives the compactness and solidity to the so-called "stone-ware." But the hardest and most refractory Berlin porcelain used in the chemical laboratory has a composition represented by silica 72.96 per cent., alumina 24.78 per cent., lime only 0.104 per cent., magnesia and iron only traces, and alkalies 1.22 per cent. The clay used at the Royal Porcelain Manufactory at Sèvres (Fr.), contains silica 58.0 per cent., alumina 34.5 per cent., lime 4.5 per cent., potash 3.0 per cent., being thus more plastic and more fusible than that used at Berlin. These wares are of considerable variety, and the glazing or more fusible glass or enamel with which they are coated in a second burning, penetrating the porous burnt clay, converts the whole into a homogeneous, compact, translucent material.

Potter's clays, as compared with fire-clay or porcelain clay, are generally more plastic and adhesive than those, because of their larger proportion of alumina. They are found in every condition of purity, but contain notable proportions of the fluxing materials. Plastic clays or potter's clays may vary in composition greatly: the silica from 42 to 70 per cent., the alumina from 20 to 40 per cent., the iron oxide from 1 to 15 per cent. or more, the lime from 0.5 to 5 per cent., the alkalies from 0.5 to 2 or 3 per cent., producing wares more or less refractory, firm, porous, and colored, and applicable not only in the highly artistic pottery and terra-cotta, so useful and durable in architectural ornamentation, but in the drain pipes and tiles and the ordinary building bricks.

For all these purposes, except for the manufacture of fine porcelain ware, the clays of Kentucky are applicable, requiring only the hand of the skilled workman, and the proper use of capital, to make them profitable.

TABLE K.

AVERAGES OF THE COMPOSITION OF THE MARLS AND MARLY CLAYS AND MARLY SHALES OF THE SEVERAL GEOLOGICAL FORMATIONS OF KENTUCKY (*dried at 212° F.*)

	Silica.	Alumina.	Iron peroxide.	Lime.	Magnesia.	Phosphoric acid (P_2O_5).	Potash.	Soda.	Water and loss.
TERTIARY—MARL.									
Fulton Co. Vol. V, N. S, p. 432—No. 2142 (*a*)	68.860	12.980	2.240	9.587	1.182	n. e.	1.773	1.278	2.100
COAL-MEASURES—MARLY SHALES.									
Boyd Co. Vol. I, N. S., p. 160—No. 1292 (*b*)	†77.560	12.643		.269	.929	.217	*1.387	*.080	5.830
Carter Co. Vol. I, N. S., p. 180—No. 1343 (*a*)	66.060	23.726		.168	.060	.127	2.093	2.273	5.300
Union Co. Vol. 2, O. S., p. 267—No. 220 (*b*)	†32.670	6.700		28.486	.698	.280	.310	.166	n. e.
UPPER SUB-CARBONIFEROUS—MARLS, MARLY CLAYS AND SHALES.									
Breckinridge Co. Vol. 2, O. S., p. 138—No. 312 (*marly shale*) (*b*)	†78.680	12.170		.351	.413	.101	.556	.190	6.720
Grayson Co. Vol. IV, N. S., p. 70—Nos. 1788–93, inclusive (*average of 6 marly shales*), (*b*)	†61.190	22.863		*c*1.432	2.623	.495	*a*4.837	*a*.752	6.529
Grayson Co. Vol. I, N. S., p. 220—No. 1446 (*marly shale*) (*b*)	†71.580	19.133		.269	.353	.267	2.910	.052	6.230
Grayson Co. Vol. I, N. S., p. 220—No. 1446 (*same by fusion*) (*a*)	60.060	14.130	13.480	.538	1.158	.280	4.625	.783	6.000
Nelson Co. Vol. 3, O. S., pp. 358–9—Nos. 726 and 728 (*average of 2 marls*) (*b*)	†85.415	10.640		.346	1.249	.117	.703	.355	1.127
Nelson Co. Vol. 4, O. S., p. 238—Nos. 1189 and 1190 (*average of 2 marly clays*) (*a*)	53.480	14.154	9.840	4.021	.802	.671	2.107	.122	11.900
Average composition of the 3 analyzed by fusion (*a*)	55.670	14.145	11.053	2.860	.921	.540	2.950	.342	9.933

TABLE K.—AVERAGES OF THE COMPOSITION OF THE MARLS AND MARLY CLAYS AND MARLY SHALES OF THE SEVERAL GEOLOGICAL FORMATIONS OF KENTUCKY—Continued.

	Silica.	Alumina.	Iron peroxide.	Lime.	Magnesia.	Phosphoric acid (P2 O5).	Potash.	Soda.	Water and loss.
LOWER SUB-CARBONIFEROUS—WAVERLY.									
Jefferson Co. Vol. V, N. S., p. 444—Nos. 2166-7 (*average of 2 marly shales*) (*a*)	60.370	20.340		1.674	1.058	n. e.	4.678	.649	6.230
Meade Co. Vol. V, N. S., p. 224—No. 2066 (*under clay*) (*b*),	†82.125	11.604		.025	.538	.156	1.082	n. e.	.650
Nelson Co. Vol. V, N. S., p. 461—No. 2216 (*marly clay* (*a*),	61.100	24.200		4.904	1.542	n. e.	4.101	.821	3.332
Average composition of the 3 analyzed by fusion, &c. (*a*),	60.607	21.637		2.751	1.219	n. e.	4.486	.706	5.197
BLACK SLATE ("OHIO SHALE") FORMATION.									
Madison Co. Vol. 4, O. S., p. 212—No. 1124 (*the "Devonian Shale"*) (*b*)	63.120	8.560		6.261	2.034	.143	1.363	n. e.	*d*12.00
"CRAB ORCHARD SHALE" (CLINTON SHALE?)									
Madison Co. Vol. V, N. S., p. 446—Nos. 2186-7 (*average of 2 marly shales*) (*a*)	45.540	19.080	3.680	10.637	.479	n. e.	3.573	.295	n. e.
UPPER SILURIAN FORMATION.									
Jefferson Co. Vol. 4, O. S., p. 192—No. 1069 (*marly shale*) (*a*)	59.900	7.260		15.053	.803	.694	.965	.012	2.196
UPPER HUDSON FORMATION.									
Henry Co. Vol. I, N. S., p. 265—No. 1577 (*indurated marl*) (*a*)	23.700	7.146	11.040	24.954	.310	1.164	2.100	.623	8.396
Jefferson Co. Vol. V, N. S., p. 444—No. 2165 (*marly shale*) (*a*)	47.960	*g*21.340	6.600	5.824	3.524	n. e.	5.264	.250	9.238
Average composition of the 2 Upper Hudson marls (*a*)	35.830	14.243	8.620	15.189	1.917	n. e.	3.682	.436	8.567

MIDDLE HUDSON FORMATION.									
Grant Co. Vol. 4, O. S., pp. 158-9 – No. 990 (*marly shale*) (*b*)	†71.280	16.250		2.789	1.564	.310	.988	.178	1.532
Grant Co. Vol. 4, O. S. pp. 158-9—No. 991 (*marly shale*) (*b*)	†78.480	12.340		1.557	.574	.630	.957	trace.	3.074
Grant Co. Vol. V, N. S., p. 198 – No. 2114 (*under clay*) (*b*)	†75.240	15.273		1.282	.383	.823	*h*1.124	.019	4.950
Grant Co. Vol. V, N. S., p. 199 — No. 2117 (*under clay*) (*b*)	†60.967	27.353		2.551	.266	.457	*i*1.585	.125	4.675
Owen Co. Vol. 4, O. S., p. 244 — No. 1203 (*marly shale*) (*b*)	†29.240	19.940		19.365	2.518	.934	.649	0	8.998
Average composition of the 5 marly shales (*b*)	63.041	18.231		5.508	1.061	.631	1.061	.064	4.409
LOWER HUDSON FORMATION.									
Campbell Co. Vol. I, N. S., p. 171—Nos. 1317-8 (*average of 2 marly shales*) (*a*)	54.750	30.470		2.103	1.195	.189	3.584	.776	4.550
Campbell Co. Vol. I, N. S., p. 178 – Nos. 1335-6 (*average of 2 marly shales*) (*a*)	55.710	14.527	13.525	3.461	.472	.145	3.884	.999	4.114
Fleming Co. Vol. 4, O. S., p. 150 — No. 972 (*marly clay*) (*a*)	39.780	10.401	10.760	9.453	6.385	.079	1.147	n. e.	13.900
Franklin Co. Vol. I, N. S., p. 212—No. 1434 (*marly shale*) (*a*)	52.060	18.831	9.200	3.666	1.210	.319	5.402	.720	7.672
Kenton Co. Vol. I, N. S., p. 270 – Nos. 1585-6 (*average of 2 marly shales*) (*a*)	45.310	21.920		13.210	.760	.367	2.374	1.252	4.530
Mason Co. Vol. 4, O. S., p. 216—No. 1130 (*marl*) (*b*)	†78.180	8.020		4.133	3.105	1.040	.722	.170	.791
Average composition of the 8 marls, &c. (excluding No. 1130), (*a*)	50.422	26.035		7.582	1.556	.225	3.279	.957	5.996
TRENTON FORMATION.									
Fayette Co. Vol. 2, O. S., p. 160—Nos. 509-10 (*average of 2 under clays*) (*b*)	†73.434	19.753		.367	.230	.407	.309	.121	n. e.
Fayette Co. Vol. V, N. S., p. 422 – No. 2120 (*marly clay*) (*a*)	53.780	23.260	1.300	4.866	.568	.191	7.612	.550	7.873

TABLE K.—AVERAGES OF THE COMPOSITION OF THE MARLS AND MARLY CLAYS AND MARLY SHALES OF THE SEVERAL GEOLOGICAL FORMATIONS OF KENTUCKY—Continued.

	Silica.	Alumina.	Iron peroxide.	Lime.	Magnesia.	Phosphoric acid (P_2O_5).	Potash.	Soda.	Water and loss.
BIRDSEYE FORMATION.									
Franklin Co. Vol. I, N. S., p. 211-12—Nos. 1431-2 (*average of 2 marly shales*) (*b*)	†73.720	12.905		.841	1.548	.447	*f*3.526	.180	5.875
Franklin Co. Vol. I, N. S., p. 213—No. 1433 (*marly shale*) (*a*)	50.360	16.816	6.997	8.736	.936	.217	3.623	1.730	8.309

† Silica and insoluble silicates.
[a] Analyzed by fusion.
[d] Water and bituminous matters.
[g] Including the phosphoric acid.
[*] Analyzed by fusion with $CaCl_2$ and NH_4Cl it gave 3.989 per cent. of potash and .639 per cent. of soda.
[b] Analyzed by acids.
[e] No. 2183 contains 19.285 per cent. of gypsum.
[h] Total potash obtained by fusion, &c., equals 3.534 per cent.
[c] Equal to 2.557 per cent. lime carbonate.
[f] Total average potash by fusion equals 7.804 per cent.
[i] Total potash obtained by fusion, &c., equals 3.072 per cent.

TABLE L.

GENERAL AVERAGES OF THE COMPOSITION OF THE MARLS, MARLY CLAYS, AND MARLY SHALES OF THE SEVERAL GEOLOGICAL FORMATIONS OF KENTUCKY (*dried at 212° F.*)

	Silica.	Alumina.	Iron peroxide.	Lime.	Magnesia.	Phosphoric acid ($P_2 O_5$).	Potash.	Soda.	Water and loss.
Composition of 1 Tertiary marl (*a*)	68.860	12.980	2.240	9.587	1.182	n. e.	1.773	1.278	2.100
Composition of 1 Coal-measures marly shale (*a*)	66.060	23.726		.168	.060	.127	2.093	2.273	5.300
Average composition of 2 Coal-measures marly shales (*b*),	†55.115	9.671		14.377	.813	.249	.849	.123	n. e.
General average of 3 Upper Sub-carboniferous marly shales, &c., (*a*)	55.670	14.145	11.051	2.860	.921	.540	2.950	.342	9.933
General average of 3 Lower Sub-carboniferous marly shales, &c., (*a*)	60.607	21.637		2.751	1.219	n. e.	4.486	.706	5.197
Composition of 1 Black Slate shale (*b*)	63.120	8.560		6.261	2.034	.143	1.363	n. e.	*d*12.000
General average of 2 Clinton shale marly shales, &c., (*a*),	45.540	19.080	3.680	10.637	.479	n. e.	3.573	.295	n. e.
Composition of 1 Upper Silurian marly shale, &c., (*a*)	59.900	7.260		15.053	.803	.694	.965	.012	2.196
General average of 2 Upper Hudson marly shales, &c., (*a*),	35.830	14.243	8.620	15.189	1.917	n. e.	3.682	.436	8.567
General average of 5 Middle Hudson marly shales, &c., (*b*)	63 041	18.231		5.508	1.061	.631	1.061	.064	4.409
General average of 8 Lower Hudson marly shales, &c., (*a*),	50.422	26.035		7.582	1.556	.225	3.279	.957	5.996
Composition of 1 Trenton marly clay (*a*)	53.780	23.260	1.300	4.866	.568	.191	7.612	.550	7.873
Composition of 1 Birdseye marly shale (*a*)	50.360	16.816	6.997	8.736	.936	.217	3.623	1.730	8.309

† Silica and insoluble silicates. *a* Analyzed by fusion, &c. *b* Analyzed by digestion in acids, &c. *d* Water and bituminous matters.

The number of these marls and marly clays, &c., which have been brought into comparison, viz: thirty from eleven different groups, is too small to show the influence of the several geological formations on their composition. So far as these go, they show the Tertiary, Coal-measures, and Middle Hudson marls to be the most silicious; the Upper Hudson, Upper Silurian, Clinton, Coal-measures, Tertiary, Birdseye, and Lower Hudson marls contain the most lime; those from the Upper Silurian, Middle Hudson, and Upper Sub-carboniferous groups contain the most phosphoric acid; those from the Trenton, Lower Sub-carboniferous, Upper Hudson, Birdseye, Clinton, and Lower Hudson groups are richest in combined potash; and soda is in largest proportions in the marls from the Coal-measures, Birdseye, Tertiary, and Lower Hudson groups.

Marls are impure clays of variable composition, generally containing a considerable proportion of carbonate of lime. They pass, on the one hand, into clays proper; on the other, into limestones; while they may shade into iron ores as their variable proportions of iron oxide increase. They are usually, even when in the hardened state of shale, readily disintegrated by exposure to the atmospheric agencies. The earliest use made of them was on the soil to increase its fertility, which it was supposed to do mainly by supplying lime where it was deficient, or by altering the consistence of the soil when too compact and heavy, or too sandy and light. For such uses the question of the cost of transporting and applying the large quantity required to alter the physical character of a soil is a serious one, and hence the modern use of marls is mainly restricted to those which contain much lime, or which are found to have much potash or phosphoric acid in their composition.

It is found, however, that the potash and phosphoric acid, although contained in some of these marls in notable proportions, are not readily or quickly available as elements of plant nourishment; the former being probably in firm combination with the silicate of alumina, and the latter forming insoluble phosphates of iron and alumina. So that, like a subsoil or under-clay, in which chemical analysis demonstrates the presence of considerable proportions of these essential materials, they prove at first less suitable to vegetable growth than the more porous surface-soil, which contains less potash or phosphoric acid, but which is darker colored by the humus which it contains.

In the course of time, by the action of the atmospheric elements and of the humic acids derived from the decay of the vegetable matters on the surface, or more quickly by admixture with stable manure, the potash and phosphates of the sterile subsoil, marl, or under clay are brought into a condition available for vegetable nourishment, and the partly exhausted surface-soil is renovated by the admixture. Gardeners and farmers have found by experience that the gradual mixture of marls, or heavy marl-like subsoils, together with the use of materials to furnish humus, is the best practical mode of making them useful in renovating the exhausted surface-soil.

This result of the experience of the practical farmer shows, no doubt, how these marls may be most profitably used. It is said by some observers that admixture of caustic lime with the marls will aid in the separation of the potash and phosphoric acid; and it is known that to calcine them in mixture with lime or carbonate of lime and calcium chloride, such as is abundantly thrown away in the bitter water which drains off from salt at the salt-works, will fully liberate the potash; but this is unavailable on a large scale because of its cost, and consequently, it appears that the best probable method of using these rich marly clays, marls, or subsoils on the exhausted soil, is to spread them on the surface, mixed preferably with slaked lime, and then to sow the land with clover, which, after a year or two of growth and pasturage, will supply to the soil, when plowed in, a large amount of vegetable matter to form humus, which will greatly aid in the chemical decomposition of the marl, and in improving the productiveness of the soil.

As may be inferred from their composition, some of these Kentucky marly clays may be employed in making some forms of pottery, terra-cotta, &c., especially the so-called stoneware, which is hard and compact because of the softening or partial fusion of the clay in the heat of the kiln, and which is glazed with common salt only. For the various forms of *terra-cotta*, and architectural appliances and ornaments, the tints which some of these clays assume on burning would make them more appropriate. Ground and calcined with a proper proportion of lime, several of these marly clays, especially those containing much alkali, would no doubt make good Portland cement, the most durable of water cements; used in large structures, mixed with more or less sand, gravel, and pebbles, &c., as the *Bèton* of the French.

When the oxide of iron is in large proportion in a hydrated state, these clays may be advantageously employed as materials for painting, as pigments of various tints of yellow, orange, red, and brown, having the names of boles, ochres, red chalk, terra sienna, umber, &c., &c. These, when calcined, assume other colors—the yellows changing to reds, &c., &c. They are among the cheapest and most durable of common pigments. The published Kentucky Geological Reports give several examples of such ferruginous clays.