MISSISSIPPI STATE GEOLOGICAL SURVEY

E. N. LOWE, Director

BULLETIN No. 13

Preliminary Report on the

MARLS AND LIMESTONE OF MISSISSIPPI

By

WILLIAM N. LOGAN

1916

PLATE I.

FIG. —. A Group of the Shells and Bones Which Compose a Part of the Selma Chalk.

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TUCKER PRINTING HOUSE JACKSON

STATE GEOLOGICAL COMMISSION.

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W. L. Kennon........*Assistant Geologist*

E. M. Jones........*Assistant on Soil Survey*

LETTER OF TRANSMITTAL.

Jackson, Miss., Sept. 21, 1916.

To Governor Theodore G. Bilbo, Chairman, and Members of the Geological Commission.

Gentlemen: I have the honor to submit herewith a report on Marls and Limestones of Mississippi, by Dr. William N. Logan. This report is valuable and timely, and I recommend that it be published as Bulletin No. 13 of the Mississippi Geological Survey.

Very respectfully,

E. N. LOWE, Director.

ACKNOWLEDGMENTS.

A considerable number of analyses of limestones were submitted by the Director after the manuscript of the report had been completed. These have been inserted at appropriate places.

All analyses, except where otherwise credited, were made by Dr. W. F. Hand, the State Chemist.

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INTRODUCTION

THE application of mineral fertilizers to the soils of Mississippi is of paramount importance to its agricultural development. That much of its soil is deficient in certain minerals cannot be disputed. That other soils which are now fertile will become deficient in certain minerals is not to be gainsaid. That many of our soils, even our upland soils, are so deficient in lime as to be acid has been demonstrated by hundreds of field tests. That the growing of alfalfa on some of our soils can be accomplished by the application of lime to these soils and not otherwise is a matter of record. That the yield of many of our common field crops has been increased by the application of lime and ground limestone is an established fact. All of these demonstrable facts convince one of the importance, to the citizens of the State, of the subject selected for this report, the marls and limestones for agricultural purposes; and has led the writer to a study of our resources along these lines. The results obtained and the co-ordinate facts gathered are set forth in this publication which the writer hopes will prove of value to those interested in the development of our agricultural resources.

There are many localities in the State where limestone suitable for agricultural purposes may be obtained. Before, however, any great expense in the preparation and the application of this limestone is incurred an analysis should be obtained of the limestone as a test of its value for liming purposes. There are many so-called lime deposits in the State which are not limestone at all but are composed of either white clay or white silica and are utterly valueless for liming purposes. Many of the so-called marls are also devoid of fertilizing constituents.

Soil Acidity.

Free acids in soils are detrimental to the growth of most crops. There are some forms of vegetation which seem to thrive best under acid conditions but farm crops in general do not produce well in the presence of soil acidity. Acidity in Mississippi soils has received the attention of the writer during a series of years of field and experimental work. Hundreds of field tests have been made and acid conditions were found to obtain in many types of both bottom and upland soils. The vastness of such acid-soil areas is a matter of surprise and concern. Some of the soils tested gave an acid reaction when the clear water solution from them was tested with blue litmus paper. However such soil areas are not believed to be large as in the majority of cases it was necessary to bring the soil particles in direct contact with the litmus paper in order to get the reaction which consists in changing the blue coloring matter of the paper to a red or pink color.

There are at least two ways by which the above named reaction may occur. The reaction has been commonly accounted for by saying that the soil contains complex organic acids which are insoluble in water but which give the acid reaction when brought in direct contact with the litmus paper which is enclosed by the soil particles. Another explanation is that the acid reaction is due to the absorption of the base of the litmus paper by the colloidal matter present in the soil.

Causes of Soil Acidity.—There is no doubt that the presence of organic acids in the soil is often responsible for soil acidity. Such soils usually have an abundance of organic matter the decay of which produces the acids. The peaty soils of shallow lake basins and marshes and the soils of poorly drained alluvial bottoms are typical examples.

Soil acidity is less frequently caused by inorganic acids produced in the soil by weathering processes. Soils formed from lignite-bearing rocks usually contain quantities of iron pyrite which in the process of decomposition forms sulphuric acid. The chemical reaction may be as follows: 2FeS 150 4H O Fe O 4H SO. Soils deficient in lime are soon depleted of their lime content and become acid. Some upland soils owe their acidity in part at least to the oxidation of sulphides. A soil that contains only a small amount of lime will soon become acid through the leaching action of meteoric water and through the loss sustained by the solvent action of plants. Rainwater contains small quantities of carbonic and other acids which aid in dissolving lime compounds some of which are moderately soluble even in acid-free waters. The organic acids exuding from the roots of plants aid in the lime-leaching process. The use of commercial fertilizers which contain free or partially free acids may reduce a soil even moderately deficient in lime to an acid condition. When an acid phosphate which is composed of monacalcic and dicalcic phosphate is applied to a solid containing lime compounds some of the lime is used up in converting the monocalcic and the dicalcic phosphates into tricalcic phosphates.

Measuring the Degree of Acidity.—The litmus paper test tells us that acid is present in the soil but it does not tell us how much is present. It is a decisive qualitative test but not a decisive quantitative test. It is important that we should know the amount of acid present in the soil in order that we may know how much lime carbonate or limestone must be added to the soil to correct the acidity. Thus far no very accurate method has been employed for the quantitative determination of acidity in soils. In the absence of such accurate method it becomes necessary to resort to experimentation. The chemical analysis of the soil will show the per cent of calcium present but it will not show in what form it exists and it is essential that it be in the carbonate form. Sometimes the calcium present is locked up in insoluble silica compounds which have no influence in correcting soil acidity. In experimenting to determine the lime needs of the soil a small area should be selected. If the soil is not suspected of being strongly acid it is probable that the best plan to follow would be to apply one ton of ground limestone per acre and note the increase in yield over that of an untreated area. If there is an increase in yield and the soil still gives the acid reaction continue the treatment as long as the results will justify. In case the soil gives poor yields of legumes and is suspected of being markedly deficient in lime it may be best to apply three or four tons per acre at the first application and the growing of alfalfa may require the application of from four to six tons per acre. There is little danger of applying too much ground limestone to the soil since applications up to one hundred tons per acre have been made with only beneficial results. There is danger, however, of applying too much caustic lime to the soil as it may cause too rapid conversion of organic matter and the loss of the organic content of the soil. On the other hand the ground limestone will cause no loss of organic matter but will remove the acidity thus creating favorable conditions for bacterial development and plant growth. The addition of lime will also improve the texture of a clay soil and may slightly increase the retentiveness of moisture in a sandy soil.

Since an acid soil contains no available lime carbonate enough lime carbonate must be added to neutralize the acid and in addition whatever amount is needed for the growing of crops. If it should require one ton per acre to neutralize the acid then for every two tons applied one ton will be available for the use of plants.

Uses of Lime in Agriculture.—The calcium contained in lime or in limestone is used by the plant as food. Many soils contain enough calcium for the growth of plants but some soils are deficient in calcium and need this element more than they do some of the more expensive elements which are so frequently applied to them in commercial fertilizers. Lime or limestone must be added to some soils then to increase the percentage of calcium needed as a plant food if the highest productivity is to be obtained.

Ground limestone is useful in correcting the acid or sour condition existing in certain soils. Acidity not only checks the vital processes of most plants but it prevents the growth and development of bacteria in the soil. Leguminous crops which are the great restorers of nitrogen to the soil cannot thrive under acid conditions. It is clear then that limestone or lime is absolutely essential to an acid soil if the best results are to be obtained in the growing of crops.

Dr. Cyril G. Hopkins in "Farm Truth No. 1," says: "The initial application of four tons per acre of ground limestone, with subsequent applications of two tons per acre every four years, will make and maintain a limestone soil on every Southern farm; and this is the first great economic step to be taken in that positive soil enrichment which is needed to treble the average acre-yield of the land now under cultivation and to restore to profitable agricultural uses the vast areas of tillable land now lying neglected or agriculturally abandoned in most Southern States."

Lime also has the power of improving the texture of the soil so that it may become more pervious to water and air both of which are essential to the successful growth of plants. It prevents clay soils from packing, baking and cracking; renders it easier to plow and cultivate and makes it a better medium for the growth of plants, bacteria and the other micro-organisms of the soils which require water and air for their growth. It also promotes the decay of organic matter by assisting bacterial growth and development.

What Form of Lime to Apply.—Lime may be applied to soil in the form of caustic lime (quick lime), (CaO); as hydrated lime ($Ca OH_2$); as lime carbonate, limestone ($CaCO_3$); as dolomite, magnesian limestone ($MgCa\ CO_{3, 2}$); or as calcium sulphate, gypsum, ($CaSO_4$, $2H\ O$).

Quicklime.—Every 100 pounds of pure quicklime contains 77 pounds of calcium which is available for uniting with the acids in the soil. So far as the percentage of calcium is concerned this is the most economical form of lime to use. However this form may be more harmful than the neutral forms since it may cause the humus of the soil to be dissipated. Under the action of quicklime the organic matter of the soil is rapidly converted into soluble compounds which are carried away by the solvent action of percolating water. In this way the element nitrogen, so essential to plant growth, becomes depleted. The investigations carried on in many experiments have demonstrated that the application of quicklime is not as beneficial as other forms of lime. Upon coming in contact with the moisture of the soil the unslaked lime will be converted into hydrated lime and heat will be evolved.

The long period of time during the year which is favorable to bacterial activity in our Southern soils renders the destruction of the organic content of the soil much more rapid than in the more northern soil provinces. The soluble nitrogenous compounds thus formed are rapidly carried away by the abundant and in many instances excessive rainfall. If we add to this natural depletion the destructive action of caustic lime we may have impoverished rather than enriched the soil. It will therefore be found more economical to pay a little more freight and apply the milder form of lime, namely ground limestone.

Hydrated Lime.—This form of lime is commonly called slaked lime. When water is added to quicklime it unites chemically with the lime (CaO) and forms hydrated lime or slaked lime, ($CaOH_2$). The amount of calcium in 100 pounds of hydrated lime is 54 pounds, if it is pure which is rarely the case. When water is added to quicklime heat is evolved and care is necessary to prevent the lime from being dead burned and to prevent fires when water accidentally comes in contact with quicklime. The effect of hydrated lime when applied to the soil is caustic and like the quicklime aids in the destruction of organic matter. Not as much care is necessary in shipping it as in the case of the caustic lime.

Origin of Quicklime and Hydrated Lime.—The mineral calcite is composed of calcium carbonate ($CaCO_3$) and is the mineral of which limestone is principally composed. Calcite is formed by the union of one part of the element calcium, one part of the element carbon and three parts of the element, oxygen. By the application of heat the compound ($CaCO_3$) may be separated into (CaO) quicklime or caustic lime and (CO_2) carbon dioxide, a gas. Every 100 pounds of pure calcite contains 56 pounds of quicklime and 44 pounds of carbon dioxide gas. Pure limestone is composed of pure calcium carbonate (calcite) so the burning of 100 pounds of pure limestone will produce 56 pounds of quicklime. When water is applied to the quicklime it is changed to hydrated lime. Heat is evolved because the water unites chemically with the quicklime. The reaction is as follows: ($CaCO_3+H_2O=CaOH_2$), hydrated lime. The 56 pounds of quicklime, obtained from every 100 pounds of pure limestone, will unite with 18 pounds of water making 74 pounds of hydrated lime. If the hydrated lime is exposed to the air it will gradually take up carbon dioxide, give off water and return to the form of calcium carbonate.

Limestone.—Limestone is calcium carbonate ($CaCO_3$). Every 100 pounds of limestone contains 56 pounds of calcium oxide and 40 pounds of calcium. The remainder of the compound is carbon dioxide. The limestone is neutral and its action on the constituents of the soil is not caustic. It has the effect of supplying calcium and of correcting acidity without destroying the organic matter too rapidly. Experiments at a number of experiment stations have demonstrated that the use of ground limestone produced greater yields over a period of years than the use of caustic lime. The use of the ground limestone is recommended above that of caustic limes notwithstand the fact that the latter contains more calcium per 100 pounds and therefore has a higher power to correct soil acidity. Continued experiments in Illinois, New York, New Jersey, Ohio, Pennsylvania, Tennessee and other states have demonstrated that ground limestone is an efficient economic aid to crop production. The Maryland Experiment Station found, "that the carbonate of lime gave decidedly better results than the caustic lime." (See Hopkins in Farm Truth No. 1). "After twenty years results had been secured, the Pennsylvania Experiment Station reports data showing that the land treated with ground limestone had produced per acre during the twenty years, 99 bushels more corn, 116 bushels more oats, 13 bushels more wheat and 5½ tons more hay than the land treated with caustic lime."

Forms of Limestone.—As has been stated pure limestone is composed of the mineral calcite. Absolutely pure limestone is of rare occurrence. It probably reaches its highest degree of purity in marble which is the crystalline form of limstone and is composed for the most part of crystals of calcite. Impurities in limestone may be either mechanically mixed or chemically combined. The most common chemically combined elements are magnesium and iron. When the percentage of magnesium reaches a certain degree the rock becomes a dolomite or magnesian limestone. The magnesian limestone may have the same color and general appearance of an ordinary limestone but it is not as soluble in acids as the latter. The impurities which are usually mechanically mixed with limestone are quartz, (sand grains), mica, clay, pyrite, amorphous phosphates and other substances. There are many different kinds of limestone depending on the origin and composition. Some of the more common kinds are chalk, coquina, marl, compact limestone, magnesian limestone and marble.

Chalk.—This form of limestone is a fine-grained variety composed of shells and fragments of shells of microscopic animals (Protozoans) which live beyond the littoral zone of the sea in relatively clear water. The color of the chalk is variable. The unweathered portions are likely to be of a bluish or greenish tint, while the weathered chalk is usually white, yellow or red. The degree of variation from white is due to the amount of oxide of iron or other minerals in the rock. As is true of other varieties of limestone, chalk may contain clay, sand and other impurities. It frequently contains nodules of calcium phosphate, pyrite and not unfrequently grains of glauconite. It disintegrates more rapidly than the more compact forms of limestone, and the erosion of its surface is more rapid. The type of soil formed on its surface depends upon the character of its impurities. Calcareous clay soils may result from its disintegration and decomposition or a sandy type of soil may be derived from it. Chalk usually contains a high per cent of lime and is easily crushed and is therefore of value for agricultural uses.

Coquina.—Coquina or shell rock as it is commonly called is composed of shells or fragments of shells of animals of macroscopic size which inhabit the littoral zone of the ocean. These shells become broken up and cemented together by wave action forming a coarse-grained porous rock in which the character of its make-up is clearly revealed. Although it has not the strength of some other forms of limestone it has been used for building purposes, for road metal and in the manufacture of lime. Because of the high per cent of lime which it contained it is valuable for the liming of lands but the shells are not as soluble as some other forms of limestone.

Marl.—Marl is an admixture of clay and carbonate of lime. The lime carbonate is usually in the form of shells with small quantities of other substances such as sand, iron compounds, glauconite, mica and gypsum. Shell marl is a mixture of shells and clay or sand.

Micaceous marl contains the mineral mica in considerable quantities. Chalk marl is a mixture of microscopic shells, clay and sand. Glauconitic or green-sand marl contains the mineral glauconite and is a valuable fertilizer because of the presence of compounds of phosphorous, potassium and lime.

Beds of marl may become indurated by the percolation of water containing minerals in solution. These cementing minerals may be compounds of iron, calcium carbonate or silica. Such indurated marls require crushing before they can be applied to land for agricultural purposes. On the other hand some beds of marl are loose and incoherent and require no special preparation before being applied. The value of the marl depends upon the per cent of plant food which it contains. They may run high in carbonate of lime and also contain appreciable amounts of magnesium, phosphorous and potassium.

Compact Limestone.—This variety of limestone has the greatest density of all the varieties except marble. It is composed of small grains of lime carbonate and it may contain the impressions of shells. Its degree of hardness varies, but as a rule it will require crushing before it can be applied to the soil. It occurs in layers which are intersected by joints and for this reason it may be quarried without much difficulty.

Dolomite, Magnesian Limestone.—The element magnesium is often combined with calcium in limestone forming, CaMg, $(CO_{3},{}_{2})$. Dolomite when present in the soil not only furnishes calcium but also magnesium for the use of the plants. It is also more useful than pure calcium carbonate in correcting acidity since 184 pounds of the former is equivalent to 200 pounds of the latter. Magnesium limestone is not as readily soluble as the calcium carbonate and for that reason is retained longer in the soil. For every 100 parts of calcium in dolomite there are 84 parts of magnesium.

The percentage of magnesium in the limestones of Mississippi is small. One sample of limestone from Tishomingo County contains 3.19 per cent of magnesia which is about the maximum as far as records go. The majority of samples investigated contain under one per cent of magnesium.

Investigations have not been made to determine whether the element magnesium is lacking in our soils. The amount of magnesium utilized by plants is small but nevertheless some soils are deficient in this element. It is probable that some of our Mississippi soils are deficient in available magnesium compounds since there are numerous soils in which it does not exist as a carbonate, the most available form. In such soils the application of a part of the liming material in the form of ground dolomite seems advisable. As a rule dolomitic limestone is a few degrees harder than ordinary limestone and its crushing would be a trifle more expensive.

Gypsum, Sulphate of Lime.—Gypsum or land plaster as the hydrated form of the sulphate of calcium is called is often applied to soil for agricultural purposes. It is often confused with quicklime as the calcined powdered form resembles quicklime in appearance. Gypsum may be used instead of quicklime to furnish the calcium needed for the growth of plants. It may be used to improve the tilth of clay soils. It may be used to stimulate the growth of bacteria on the roots of leguminous plants and it may be used to neutralize sodium carbonate in the soil.

Since gypsum is a neutral salt it cannot be used to correct acid conditions in the soil. It will not make a sour soil sweet. It will not change an acid soil into an alkaline or neutral soil. It does not promote the decay of organic matter in the soil as does quicklime, or calcium carbonate. Since the two last named functions, particularly the first, are of very great importance gypsum ought not to be applied to the soil except for the purposes of neutralizing sodium carbonate, and of supplying the element calcium when the other forms of lime cannot be obtained.

There are two principal forms of gypsum. Selenite is the crystalline form and gypsite is the earthy or amorphous form. The latter is more commonly used for agricultural purposes. When gypsum is ground and heated the water of crystallization is driven off and the dehydrated residue is called "Plaster of Paris." Very commonly this is the form in which gypsum is applied to the land.

Gypsum may be precipitated from sea water under the same or similar conditions to the deposition of common salt. It may also result from the decomposition of pyrite in the presence of lime carbonate. It is more soluble than lime carbonate and does not remain long in the soil. Crystals of selenite are found in considerable abundance in the Jackson clays of Mississippi.

Correction of Acidity.—For the correction of acidity in soils 56 pounds of quicklime is equivalent to 74 pounds of hydrated lime, or 92 pounds of magnesian carbonate (dolomite), or of 100 pounds of lime carbonate (limestone). That is, if all these substances are chemically pure. Other things being equal, when one ton of limestone is worth $1.00 then one ton of dolomite is worth $1.09, one ton of hydrated lime is worth $1.35 and one ton of quicklime is worth $1.79. But for reasons already stated the use of the caustic forms of lime should be limited to those soils containing a superabundance of organic matter.

Amount of Limestone to Apply.

The amount of limestone to use on a soil will depend on the quantity present in the soil. Soils deficient in lime will require from 1 to 4 tons per acre of ground limestone. The larger the grain of the crushed stone the more should be applied in a single application. After an application that would bring the total amount up to 4 or 5 tons per acre it is probable that an application of 1 ton per acre every 2 years or 2 tons every 4 years would be sufficient to maintain the lime content at its proper percentage for the best plant growth. In case a marl or an impure limestone is used the percentage of lime should be determined and the amount of such material applied be increased in proportion to the amount of impurities. For example a marl which contains only 80 per cent of lime carbonate (limestone) should be applied at the rate of 2,500 pounds for each ton required.

If the litmus paper test described in the preceding pages shows that the soil is not acid then the amount of ground limestone or calcium carbonate present may be determined by having a chemical analysis made of several samples of the soil taken from different parts of the field. Suppose the average of these samples to contain .1 per cent of calcium carbonate, the amount present in the soil would be about 1 ton per acre for a depth of about seven inches. If the average was 1 per cent then the amount of calcium carbonate would be about 10 tons per acre for the same depth of soil.

Since the probability of getting too much lime in the soil is very remote the limiting conditions are only economical. The important thing is to be sure that the soil has received enough to meet crop requirements. For the successful growing of alfalfa on an acid soil from 4 to 6 tons of ground limestone should be applied per acre. It must be borne in mind that not all soils are suited to the growing of alfalfa and that the best types of soils are the silt and the clay types.

Time of Application.

When ground limestone is to be applied to cultivated land it may be applied at any time when the dryness of the ground will permit if its application will not interfere with the growing crop. When the fields are plowed either in the fall or spring the ground limestone may be spread upon the surface and disked or harrowed in. If the application is to be of coarse material it may be spread upon the surface of the unplowed field, allowed to weather for a time and then plowed under. A second and lighter application may then be made to the surface of the plowed field.

If the Selma chalk is used it may be broken up in pieces having a diameter of three or four inches and applied to the soil in the fall. If the weather conditions are the usual ones of our winter months the limestone will be largely disintegrated by spring. If the application is to be made in the spring the rock should be reduced to a greater degree of fineness. The Vicksburg limestone will resist weathering more than the Selma chalk and should be ground to smaller particles. The Devonian and the sub-carboniferous limestones are still more resistant and require a still greater degree of fineness. Fall-applied limestone has the advantage of having a longer period of time to weather and after the crop is gathered the farmer has more time for its application.

How to Apply the Limestone.

Ground limestone may be applied by hand or by machine. In spreading by hand the limestone may be scattered from a wagon box by the use of a shovel as the team is driven back and forth across the field. Grain drills may be used for spreading lime or limestone but the small amount held by the hopper is a drawback. The limestone may be placed on the field in piles and spread by hand or machine from these piles. Dr. Hopkins, in the publication already referred to, gives the following description of a home-made spreader: "Make a hopper similar to that of an ordinary grain drill, but measuring 8¼ feet long with sides at least 20 inches wide and 20 inches apart at the top. The sides may be trussed with ⅜-inch iron rods running from the bottom at the middle to the top at the ends of the hopper. Let the bottom be five inches wide in the clear with 2-inch holes 5 inches between centers. Make a second bottom to slide under the first on straps of iron 10 inches apart, which should be carried from one side to the other under the hopper to strengthen it, also with holes to register. Both bottoms may be of sheet steel or the lower one may be of hard wood, reinforced with strap iron if necessary.

"To the lower movable bottom attach a V-shaped arm projecting an inch from under the hopper, with a half-inch hole in the point of the V, in which drop the end of a strong lever, bolting the lever loosely but securely to the hopper with a single bolt, and fasten to the top of the hopper a guide of strap iron in which the lever may move to regulate the size of the opening by sliding the lower bottom. Make a strong frame for the hopper, with a strong, well braced tongue.

"Take a pair of old mowing machine wheels of good size and with strong ratchets in the hubs, and fit them to an axle of suitable length (about 10 feet) and 1⅜ or 1½ inches in diameter. The axle should be fitted with journals bolted to the under side of the frame. Make a reel to work inside the hopper by securing to the axle, 10 inches apart, short arms of ⅜-inch by 1-inch iron and fastening to these arms four slats or beaters of ⅝-inch by ¾-inch iron about an inch shorter than the inside of the hopper, the reel being so adjusted that the beaters will almost scrape the bottom but will revolve freely between the sides. The diameter of the completed wheel is about 5 inches and it serves as a force feed."

Dr. Hopkins also makes the following suggestions regarding application: "In hauling and spreading limestone it is of first importance to save time and labor. As a rule it is far more economical to purchase in bulk and have it shipped in box cars, although wetting will do no harm except to give trouble in spreading. Bags are expensive and easily damaged, and with tight wagon boxes they are wholly unnecessary. If bags must be used in handling the limestone the purchaser should bag it when hauling from the car. As a rule the plan should be to haul the limestone directly from the car to the field, transfer from the wagon to the spreader and spread at once upon the land. With a haul of two miles or less and with two men, one boy and two teams, with three wagons and one spreader, 40 tons of ground limestone can be taken from the car and spread over 10 or 20 acres of land in three days, providing the roads and other conditions are favorable, or 30 tons can be removed from the car in two days, the last two or three loads being kept on the wagons and spread the third day if necessary. When the haul is longer one or more additional teams are needed on the road."

Fineness of Grain of Crushed Limestone.

Before being applied to land limestone must be crushed and reduced to a degree of fineness. The degree of fineness necessary will depend upon the hardness of the rock and upon the ease with which it disintegrates and dissolves. Some limestones like the Selma chalk are very soft and minute degree of fineness is not essential as even large particles disintegrate rapidly. If the crusher be adjusted to allow the larger particles an inch in diameter to pass the fineness of grain will be sufficiently small for this kind of rock. For the harder Devonian and Carboniferous rocks of this State the largest particles should not be over one fourth of an inch in diameter. The finer the grain the more rapidly will the limestone be leached from the soil by the solvent action of ground water, hence extreme fineness of grain should be avoided. On this point Dr. C. G. Hopkins in Farm Truth No. 1, page 12, says: "The advice sometimes given that limestone should be ground so that it will all pass through a screen with 50 or 100 meshes to the linear inch has no justification. Such grinding increases unnecessarily the cost of material, increases the cost of application (by requiring annual or frequent application) and increases the loss by leaching. Where used liberally at less frequent intervals in rational, profitable, permanent systems, an 8-mesh or 10-mesh screen is amply fine for the most economic product, especially for the ordinary limestone consisting chiefly of calcium carbonate."

It should be borne in mind that if the limestone is ground so that it will all pass through a screen having 10 meshes to the linear inch that a larger part of it would pass a screen of much finer mesh.

Use of Limestone and Green Manures.

One of the most economical methods of building up the nitrogen content of the soils of Mississippi is by growing a crop of legumes and plowing under the crop after it has reached the forage-crop degree of maturity. Of course it is more profitable to feed the legume crop to stock and return the barnyard manure to the soil. But on many farms sufficient stock is not fed and green manuring may then become the most economical method of adding nitrogen to the soil. Most of the soils deficient in nitrogen are also deficient in other plant foods. Some are deficient in lime, some in potash and some in phosphorus and some in all three. Soils deficient in lime are acid or sour and the addition of green manure to such a soil would not be beneficial even if it were possible to successfully grow the crop of legumes used for the purpose. Some form of lime must be added to such a soil before it can become productive. The best form of lime to use for such a purpose is ground limestone. It will serve to neutralize the acid in the soil and also the acids formed by the decomposition of the manure crop. The best time for its application is before the growing of the legume crop as the beneficial effects of the lime upon the soil produce a larger crop of legumes. The amount of ground limestone to apply will depend upon the degree of acidity but it will usually require from 2 to 4 tons per acre.

If the soil is deficient in phosphorus this should be supplied in the form of ground phosphate rock before the growing of the crop of legumes. Not much of the phosphorus will become available for the legume crop but a little will become available and the growth of the crop increased thereby. To assure the best growth of the legumes the soil ought to be inocculated with bacteria which will aid in the growth of the legume plant and in the fixing of nitrogen from the air. This inoculation may be made by the addition of barnyard manure to the soil or by the addition of soil from a field where this legume had been successfully grown, or a pure culture of the organism may be applied to the seed of the legume before planting. Closely allied legumes are the hosts of similar organisms and these are interchangeable for such plants. The soil prepared for mellilotus, alfalfa or burr clover may be inoculated with soil taken from the fields where any of these have been grown. In the same way the organisms of red clover, alsike, white clover and crimson clover are interchangeable; those of the cowpea and the partridge pea; and those of the common vetch and of the hairy vetch.

Of the total nitrogen in leguminous plants about one third is taken from the soil and two-thirds from the air. In alfalfa about 42 per cent of its total nitrogen content is contained in its roots. So that the growing of alfalfa may increase the total nitrogen content of the soil even though the hay crop be removed each year. Red clover and crimson clover will come close to returning through their roots as much nitrogen as is taken from the soil during their growth. A legume like the cowpea has only six per cent of nitrogen in its roots and so takes out of the soil more than four times as much nitrogen as it restores through its roots. It is a fallacy to suppose that the growing of such a plant in a crop rotation in which the hay crop is removed will increase the total nitrogen content of the soil.

Dr. Chas. F. Briscoe, Bacteriologist of the Agricultural and Mechanical College, has conducted some experiments to determine the bacteriological effects of green manures. He used alfalfa for the green manure. His conclusions are as follows: "1. There is a direct relation between bacterial count and the amount of organic matter added. 2. The quantitative bacteriological test and the vegetative test agree very uniformly. 3. A light dressing of stable manure with a green manure gives a marked effect as shown both by the crop grown and the bacterial counts. 4. The addition of a bacterial culture along with the green manure has as great an effect as the addition of the light dressing of stable manure which indicates that the benefit of the addition of the stable manure is due largely to the addition of the bacteria contained in the manure. 5. The addition of organic matter gives not only a larger growth but a better quality of feed as shown by the analysis for total nitrogen in the straw."

Professor C. T. Ames of the Holly Springs Branch Experiment Station in conducting some experiments to determine the value of liming in the growing of cowpeas found that the addition of 500 pounds of air-slaked lime in drill increased the amount of hay by 960 pounds and the number of bushels of peas by 8 bushels; that the addition of 500 pounds of crushed limestone per acre increased the yield of hay by 1,280 pounds and the number of bushels of peas by 5.5 bushels per acre; and that the addition of 2,000 pounds of air-slaked lime broadcast increased the yield of hay per acre by 1,660 pounds and the number of bushels of peas by 5 bushels per acre. In discussing these tests Professor Ames says: "One application of lime, at the rate of two tons of crushed stone or one ton of air-slaked lime per acre, will increase the yield of most legumes each year for several years. Lime will give better results when used under leguminous crops; however, on these soils, almost any crop will respond to the use of lime. * * * In 1912 at this Station, the yield of seed cotton was increased from 600 pounds on unlimed land to 820 pounds on soils that were limed, and the same year the yield of corn was increased 13 bushels per acre by the use of lime; that is, the unlimed soils produced 57 bushels per acre and the limed soils in the same test 70 bushels per acre. * * * We have adopted the practice of applying lime in the fall on land that has recently been turned and harrowing it in thoroughly so as to incorporate it with the soil. Such a method has proven satisfactory. * * * The successful growing of alfalfa here may be summed up in the following: 'Lime, fertility, inoculation and fall planting. Lime should be applied the fall before at the rate of from 2 to 4 tons per acre on land that was broken for this purpose. This would be a fine time to add from 10 to 20 loads of manure per acre. Plant this land the next spring in some short-lived crop such as cowpeas, potatoes, or beans; remove the crop early in July; turn the land very shallow and keep well harrowed until seed are sown. Plant 25 pounds of seed per acre, after rain, from the last of August to the middle of October, and harrow in. The seed bed should be firm. Three or four hundred pounds of soil from a well established alfalfa field will furnish sufficient inoculating material for one acre. Sow this soil on the land at seed planting and harrow in with the seed. You should get the first cutting of hay by the middle of May the next season, and this cutting should pay you for all the expense you have had, except the manure.'" Bulletin No. 165.

Limestones in Mississippi Suitable for Agricultural Use.

Mississippi contains a number of limestones suitable for grinding and applying to soils. In the northeastern part of the State, particularly in Tishomingo County, there are beds of limestone belonging to the Devonian and to the Mississippian periods. A little to the west extending from Corinth to Macon and beyond there is a belt of soft limestone called the Selma chalk which is suitable for agricultural purposes. Lying west of the Selma chalk between Houston and Ripley are the Ripley marls which can be used locally. Bordering the Selma and the Ripley areas on the west is the Clayton limestone which can be used for liming purposes. Through the central part of the State extending from Vicksburg to Waynesboro is the outcrop of the Vicksburg limestone and the marls which are associated with it. This formation contains beds of marl and layers of limestone which are suitable for use in the liming of lands. These limestones and marls vary in the percentage of lime carbonate and other plant food which they contain. They also vary in the degree of hardness and the ease with which they can be crushed. As a rule the Selma marl is the most easily crushed and the others stand in this order, Ripley, Clayton and Vicksburg about the same hardness, the Devonian and the sub-Carboniferous (Mississippian) the hardest.

The table which follows exhibits the amount of phosphorus, potassium, and lime in some of the limestones and marls of Mississippi.

Table No. 1.

Showing the per cent and pounds per ton of phosphoric acid, potash, lime and lime carbonate in Mississippi limestones.

SHOWING THE PERCENT AND POUNDS PER TON OF PHOSPHORIC ACID, POTASH, LIME AND LIME CARBONATE IN MISSISSIPPI LIMESTONES.

Locality.	Phosphoric Acid Per Cent.	Phosphoric Acid Pounds.	Potash. Per Cent.	Potash. Pounds.	Lime. Per Cent.	Lime Carbonate. Per Cent.	Lime Carbonate. Pounds.
Baldwyn	0.51	10.2	0.3080375	6.16	29.74	52.94	1958.8
Bear Creek	0.1325	2.65	0.0265375	.53	29.44	52.40	1048.0
Brandon	0.0425	.85	0.178525	3.57	46.04	81.95	1639.0
Brandon	0.12	2.40	0.062725	1.25	48.08	85.58	1711.6
Brooksville	0.36	7.20	0.275025	5.50	44.50	79.21	1655.14
Booneville	0.6325	12.65	0.193	3.86	41.52	73.90	1478.0
Corinth	0.3775	7.55	0.207475	4.15	24.20	43.07	861.4
Corinth	0.3325	6.65	0.390825	7.81	28.76	51.19	1023.8
Crawford	0.27	5.4	0.1351	2.70	46.28	82.37	1647.4
Crawford	0.3725	7.45	0.313625	6.27	39.58	70.45	1409.0
Indian Creek	0.1925	3.85	0.08926	1.78	29.60	52.68	1053.6
Jackson	0.175	3.50	0.197825	3.95	11.40	20.29	405.8
Jackson	0.2625	5.25	0.26035	5.21	14.93	26.57	1472.4
Macon	0.2725	5.45	0.197325	3.96	41.36	73.62	1472.4
Macon	0.14	2.80	0.18476	3.69	41.44	73.76	1475.2
Macon	0.165	3.3	0.1547	3.09	43.58	77.57	1551.4
Okolona	0.235	4.7	0.190545	3.81	45.88	81.66	1633.2
Okolona	0.1552	3.05	0.043425	0.86	35.67	63.49	1269.8
Okolona	0.185	3.7	0.08685	1.73	44.66	79.49	1589.8
Okolona	0.3575	7.15	0.0554975	1.109	41.44	73.76	1475.2
Plymouth	0.195	3.9	0.207475	4.15	30.18	53.72	1074.4
Plymouth	0.19	3.8	0.159225	3.18	24.40	43.43	868.6
Waynesboro	0.135	2.7	0.05996	1.19	14.48	25.77	515.4
Van Vleet	0.31	6.2	0.1351	2.7	25.66	45.67	913.4
Van Vleet	0.1625	3.25	0.16646	3.33	40.98	72.94	1458.8
Van Vleet	0.1375	2.75	0.07735	1.55	41.97	74.70	1494.0

The Geological Formations of Mississippi Containing Lime.

There are a number of geological formations in Mississippi that contain calcareous (limey) matter or marls. These vary as to the amount of lime and the proportions of other substances. They vary also in degree of hardness and hence in the ease with which they may be crushed and prepared for agricultural purposes. Some of the salient facts regarding these formations are given in the following paragraphs.

Devonian.—The Devonian period of geological time is represented in Mississippi by formations consisting of shales and limestones. The area of outcrop of these formations is small and is confined to bluffs of the Tennessee River in Tishomingo County. The limestone is a bluish-gray rock of almost flint-like fracture and of considerable hardness. Exposures occur on Yellow Creek near its mouth, on Whetstone Creek near Short, near Old Eastport on the bluff of the Tennessee River, at Bluff Spring and on Goodman and Indian Creeks. The limestone attains a thickness of 40 feet or more and consists of layers of dark, compact, non-fossiliferous rock. The individual layers attain a thickness of eight or more feet and are intersected by numerous joint planes. The following table gives the analysis of four samples of Devonian limestones from Tishomingo County, 1 and 3 from Indian Creek and 2 and 4 from Old East Port. 1 and 2 were reported by Dr. E. W. Hilgard and 3 and 4 by Dr. W. F. Hand.

Table No. 2.

ANALYSES OF DEVONIAN LIMESTONE FROM TISHOMINGO COUNTY.

Insoluble matter (SiO_2)	54.201	35.281	42.00	48.18
Alumina (Al_2O_3)	1.064	1.914	1.98	3.43
Iron oxide (Fe_2O_3)	0.903	1.581	6.02	3.13
Lime (CaO)	23.247	32.603	23.25	39.47
Magnesia (MgO)	0.788	0.630	0.27	3.19
Carbonic acid (CO_2)	15.572	27.643	24.10	5.06
Organic matter and water	3.752	....	0.40	0.40
Potash (K_2O)	0.473	0.348	....	....
Sulphur trioxide (SO_3)	....	....	1.50	2.23

Another sample of limestone from Indian Creek contained 29.60% of CaO and 52.68% of calcium carbonate. Since the highest percentage of lime carbonate shown by any of these samples is about 70% this limestone is not as good for liming purposes as some other limestones. It would have the advantage of remaining in the soil for a longer period since it disintegrates less rapidly than some other limestones of the State.

Lower Carboniferous.—Overlying the Devonian formations in Tishomingo County and outcropping in a small area in Itawamba County are beds of shale, sandstone and limestones of lower carboniferous age. The best exposures of the limestone are along the banks of Bear River and on a small creek entering Cypress Pond near Mingo Bridge. The bed of limestone exposed has a visible thickness of 15 feet but the total thickness is not exposed. One of the layers is broken up into large quadrangular blocks which have a thickness of seven feet. This limestone contains some bituminous matter, which ignites after being held for a short time in a flame. When heated, sufficient bitumen exudes to change the color from gray to black. The table given below exhibits the composition of a sample of the limestone:

Table No. 3.

ANALYSIS OF CYPRESS POND LIMESTONE.

Constituent.	Per Cent.
Moisture	1.10
Volatile matter (CO_2)	27.00
Silicon dioxide (SiO_2)	10.91
Iron oxide (Fe_2O_3)	5.00
Aluminum oxide (Al_2O_3)	8.71
Calcium oxide (CaO)	47.06
Magnesium oxide (MgO)	0.16
Sulphur trioxide (SO_3)	0.85

Since this limestone contains about 84.03% of calcium carbonate from the standpoint of lime content it is one of the best limestones in the State. It is not as easily crushed and not as readily soluble as some others.

Table No. 3a.

Analysis of Limestone from Cypress Pond. Collected by C. F. Wagner, Iuka, April, 1916.

	Per Cent
Moisture	0.06
Lime (CaO)	55.96
Calcium Carbonate, $CaCO_3$, (calculated)	99.86

Selma Chalk.—The most widely distributed and the most abundant lime-bearing formation is the Selma chalk of the Upper Cretaceous system. This formation is for the most part a fine-grained chalk or chalk marl. The outcrop of this formation extends from the northern line of the State in vicinity of Corinth to Kemper County on the south, occupying a strip of territory varying from 30 to 50 miles in width.

On unweathered surfaces the rock has a bluish tint but weathers white or yellow. The amount of calcium carbonate varies in different parts of the area but as a rule increases toward the west and toward the south. The thickness also increases toward the west and toward the south. In the northeastern part of the area the total thickness is less than 100 feet while in the extreme southwestern portion it reaches a thousand feet in thickness. The Selma chalk in many places contains minerals of potassium and of phosphorus which add to the fertility of the soil when the limestone is applied to the land.

Ripley Marls.—The Ripley formation of the Upper Cretaceous system borders the Selma chalk on the west in the northern part of its outcrop. It extends from the north line of the State above Ripley to Houston on the south, occupying the strip of territory known as the Pontotoc Ridge. The marl is a highly fossiliferous sand clay which in some places passes into a layer of shell rock of a sandy nature. The marl contains grains of glauconite which contribute to the fertility of the soils formed from the decomposition of this rock.

The Calcareous Claiborne.—Beds of greenish marl containing large numbers of shells occur in the upper portion of the Claiborne formation of the Eocene epoch of the Tertiary period in Mississippi. In some places the percentage of lime is sufficiently high to render the marl valuable for local liming purposes, though if it had to be transported by rail, it would be more economical to use a rock containing a higher percent of lime carbonate. The outcrop of this formation occupies the central part of the State in a line running from Yazoo County to Clarke County.

Silicious Claiborne.—At Vaiden there is a green sand exposed in some railroad cuts south of town. A heavy purplish-brown clay forms the principal part of the outcrop with thinner layers of green sand. The grains of the sand are dark green and yellowish-green in color. An analysis of a sample of the sand was made by Dr. Hilgard with the following results:

Table No. 4.

VAIDEN (SHONGALO) GREENSAND.

Coarse sand, and insoluble silica	36.707
Soluble (in NaO_2CO_3) silica	18.296
Potash	1.604
Soda	0.045
Lime	0.166
Magnesia	1.630
Peroxide of iron, with little alumina	34.377
Phosphoric acid	trace
Carbonic acid	0.129
Water	7.012
Total	99.948

The percentage of lime in this rock is too low to make it of use as a liming material and the other fertilizing constituents are hardly abundant enough to make it of value when applied to the soil.

The Jackson Marls.—Calcareous matter is sufficiently abundant in certain parts of the Jackson formation to render it useful locally for liming purposes. The formation borders the calcareous Claiborne on the south. It consists of beds of sand, clay and marls. The marls contain the shells and bones of marine animals. Outcrops occur on the Pearl River at Jackson, at Brandon and other places.

The Vicksburg Limestone.—The Vicksburg limestone belongs to the Oligocene epoch of the Tertiary period. The lime of its outcrop parallels the Jackson formation on the south, extending from Vicksburg to Waynesboro. It consists of beds of limestone and marls. Typical exposures occur at Vicksburg, Brandon and Byram. Exposures of limestone occur in the bluff of the river at Vicksburg. In the exposures along the river front, there are five or six layers of limestone interbedded with marl and clay. They overlie dark colored clays and sands. The limestone varies in thickness in the different ledges and even in the same ledge. The individual layers are from 1 to 6 feet thick. The following table gives the chemical composition of Vicksburg limestone from a number of exposures:

Table No. 5.

ANALYSES OF VICKSBURG LIMESTONE.

	No. 1	No. 2	No. 3	No. 4
Moisture	.40	1.00	1.79	2.10
Volatile matter (CO_2)	37.22	35.20	35.40	33.16
Silicon dioxide (SiO_2)	7.08	7.31	6.77	14.88
Iron oxide (Fe_2O_3)	2.50	4.00	2.00	3.59
Aluminum oxide (Al_2O_3)	.61	13.66	4.68	5.70
Calcium oxide (CaO)	50.44	36.62	45.51	36.86
Magnesium oxide (MgO)	1.07	.29	.64	.99
Sulphur trioxide (SO_3)	.38	2.78	3.00	.24
Total	99.70	100.86	99.79	97.72

Sample No. 1 is from Warren County; No. 2 and No. 3 are from Wayne County, and No. 4 is from Rankin County.

At Brandon, in Rankin County, there are some excellent exposures of Vicksburg limestone. On the Robinson place, 4 miles southeast of Brandon, there is a stone quarry in which six layers of limestone are found interbedded with marl in the following stratigraphic order:

Table No. 6.

SECTION OF VICKSBURG AT ROBINSON QUARRY, NEAR BRANDON.

13.	Soil and decomposed rock	2
12.	Limestone	1-1½
11.	Marl	1
10.	Limestone	2
9.	Marl	2
8.	Limestone	1¼
7.	Marl	1½
6.	Limestone	1½-2
5.	Marl	2
4.	Limestone	2
3.	Marl	1¼
2.	Limestone	2
1.	Marl	2

The limestone is bluish on fresh fractures but weathers white. It is fossiliferous, containing abundant evidence of marine life.

Grand Gulf and Pascagoula Formations.—These consist of clays, silicious clay stones, quartzites, impure lignites, sands, gravels, and to a limited extent of shell beds and marls. The lime in the marls ranges from less than one per cent to 12 per cent, the magnesia from 1 to 2 per cent; the potash from ½ to 1¼%; the phosphoric acid from .10 to .15%. A shell marl outcropping at Lyman, Harrison County, is typical of the marls of these formations. It is a dark-colored sandy clay with oyster and other shells thickly imbedded within it. The shells have undergone but little change since they were deposited, except that they are partially disintegrated and rapidly crumble when exposed to the weather.

DISCUSSION BY COUNTIES.

In the following pages the occurrence, distribution, and charac ter of the limestones and marls of the State are discussed by counties. No attempt has been made to give a complete list of the outcrops for each county but to discuss a very limited number in each county. These will probably represent the average conditions of the formations for that county.

ALCORN COUNTY.

Alcorn County contains two calcareous formations, the Selma chalk and the Ripley marls. The former in the central part of the county and the latter in the western part. The highest per cent of lime is contained in the Selma chalk of the western part of the county.

Lime-Bearing Formations Near Corinth.—At Corinth a clayey marl outcrops in a cut on the Southern Railroad just south of Confederate Park. The following is a section of the outcrop:

Section of Selma Chalk at Corinth.

SECTION OF SELMA CHALK AT CORINTH.

3.	Yellowish, fine sandy loam	10 to 12 feet
2.	Red sandy clay, indurated in places	2 to 4 feet
1.	Blue clayey marl with shells	10 x* feet

The bluish clayey lime rock contains small shells which have the appearance of young inocerami though they may be the young of ostrea or gryphea. The blue rock weathers to a gray colored rock which in turn weathers to a blue or mottled clay. The unweathered rock contains numerous small crystals of selenite which glisten in the sunlight. The overlying red sandy clay contains streaks of yellow oxide of iron. The layer is so indurated in places as to break out in large blocks. The overlying fine sandy loam may be the weathered product of the red clay but it seems to have little in common with it. An analysis of a sample of the blue lime rock is expressed in the following table:

Table No. 7.

ANALYSIS OF SELMA LIMESTONE FROM CORINTH.

Silica (SiO_2)	25.40
Alumina (Al_2O_3)	6.88
Iron oxide (Fe_2O_3)	8.62
Lime (CaO)	26.37
Magnesia (MgO)	0.58
Volatile matter (CO_2, etc.)	23.70
Sulphur trioxide (SO_3)	0.64

The lime content of two other samples was found to be 24.20 per cent and 28.76 per cent and the computed calcium carbonate to be 43.07 and 51.19 per cent. This limestone is too impure to serve as more than a local use for the liming of lands.

The exposures of Selma chalk lying farther west of Corinth near the Tennessee line are from the upper part of the formation and contain a higher per cent of carbonate of lime and would on that account be more suitable for liming purposes.

The first of the above samples contains 0.3775 per cent or 7.55 lbs. per ton of phosphoric acid and 0.207475 per cent or 4.15 lbs. per ton of potash. The second sample contains 0.3325 per cent or 6.65 lbs. per ton of phosphoric acid and 0.390825 per cent or 7.81 lbs. per ton of potash.

PLATE II.

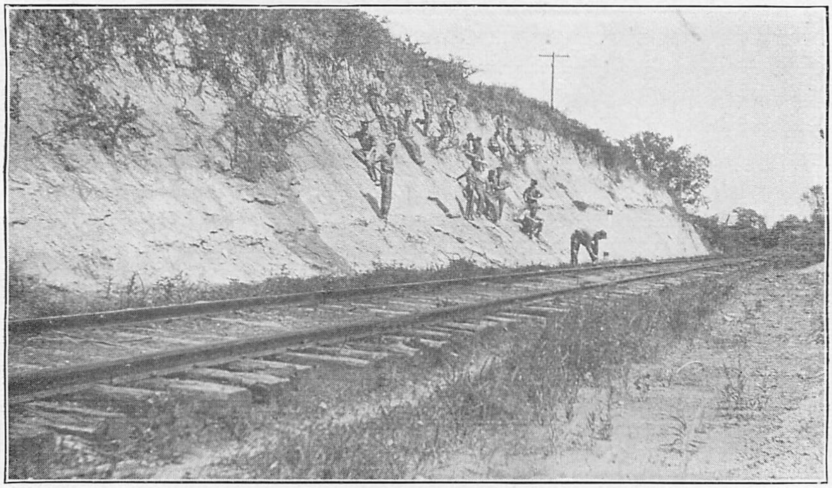


FIG. 1. The Blue Cut on the M. & O. R. R. East of the A. & M. College. An Excellent Exposure of the Selma Chalk. (Photo by Louis Roark).

FIG. 2. A View Showing Typical Erosion in the Selma on the A. & M. College Farm. (Photo by Louis Roark).

CHICKASAW COUNTY.

The eastern part of Chickasaw County is occupied by the outcrop of the Selma chalk belonging to the Upper Cretaceous. In the central portion there is a small area occupied by the Ripley marls and the Clayton limestone of the Midway-Eocene group. Both of these areas contain calcareous materials suitable for agricultural purposes.

Selma Chalk Near Okolona.—From the corporate limits of Okolona for a distance of two miles and beyond there are numerous outcrops of Selma chalk. The chalk in many places is compact and contains but few shells of macroscopic size. At a point on the Houston road two miles west of Okolona there is an outcrop of shell marl containing many large shells of gryphea and exogyra. The chalk shows at the surface in the northern part of Okolona and along the bluffs of a valley a mile or two to the north. To the east there are also outcrops containing shells and saurian bones. Along the borders of these outcrops there is a luxuriant growth of mellilotus. An exposure of the Selma chalk occurs in a cut of the railroad south of the Mobile & Ohio railroad station. Two samples of this chalk were analyzed under the direction of Dr. W. F. Hand, State Chemist.

Table No. 8.

ANALYSES OF SELMA CHALK FROM OKOLONA.

Constituent.	Sample No. 1. Per Cent.	Sample No. 2. Per Cent.
Silica (SiO_2)	8.80	8.70
Alumina (Al_2O_3)	2.86	0.00
Iron oxide (Fe_2O_3)	4.08	6.00
Lime carbonate ($CaCO_3$)	45.51	45.62
Magnesia carbonate ($MgCO_3$)	0.36	1.72
Volatile matter (CO_2, etc.)	31.11	34.40
Sulphur trioxide (SO_3)	0.38	1.11
Moisture	6.35	1.10

At another point there is at the base of the marl a layer of limestone having a thickness of two feet and a considerable degree of hardness. In weathering the limestone forms rough irregular masses. These outcrops are a part of a rather prominent ridge running north and south at a distance of eight miles east of Houston. The small valleys which receive the wash from these lime hills contain soils which are much more fertile than the average soils of the locality. The limestones and marls contain phosphoric acid, potash and lime carbonate, all essential to plant growth. The limestone contains 40.98 per cent of lime and 72.94 per cent of calcium carbonate. The marl contains 25.66 per cent of calcium oxide (lime) and 45.67 per cent of lime carbonate (limestone).

Limestone Near Houston.—About one and one-half miles north of Houston there are some outcrops of a thinly bedded limestone. It is exposed for over one hundred yards along the bed of a small creek on the west side of the railroad track. The surface of the limestone is rough and shows evidence of much weathering. The color varies from gray to light yellow. The total thickness revealed is not over twelve feet. The individual layers of limestone vary from 6 to 18 inches. This limestone also occurs in a railroad cut one mile north of Houston where it forms the cap-stone of a low ridge. A sample of limestone from this point contains 25.22 per cent of calcium oxide and 44.89 per cent of calcium carbonate. Locally this limestone could be used for liming purposes. Crushing the rock would be expensive as it is comparatively soft. Other exposures of this limestone occur along the railroad between Houston and Pontotoc. There is an exposure of white crumbly limestone in a railroad cut near Algoma. Near Gershorm the outcrops have an approximate thickness of ten feet. It is exposed in a stream channel south of New Houlka and south of Belmont there are exposures in railroad cuts and in the stream channels.

Another sample of chalk from Okolona was analyzed by Dr. Hilgard and found to contain 81 per cent of lime carbonate. Such a limestone is well adapted to the liming of lands.

More recently the writer collected samples of the Selma chalk from outcrops west and north of Okolona. Upon analysis these were found to contain the following percentages of lime and lime carbonate:

Table No. 9.

LIME AND LIME CARBONATE IN OKOLONA LIMESTONES.

	Lime. Per Cent.	Lime Carbonate. Per Cent.
Sample No. 1	44.66	79.49
Sample No. 2	35.67	63.49
Sample No. 3	41.44	73.76
Sample No. 4	45.88	81.66
Average	41.91	74.60

Table No. 9a.

Analysis of Limestone from R. R. Cut on the Houston Branch of M. & O. 1 1-2 miles west of Okolona. Collected by E. N. Lowe, April, 1916.

RESULT OF TWO ANALYSES:

	Per Cent
Moisture	1.76
Lime (CaO)	39.59
Calcium Carbonate, $CaCO_3$, (calculated)	70.64

It is evident from the above analyses that this limestone contains sufficient lime to make it serviceable for agricultural purposes. The rock is soft, easily crushed and its preparation for liming would not be expensive.

Limestones and Marls Near Van Vleet.—On the top of a hill about a quarter of a mile north of Van Vleet a shallow well has been dug penetrating a grayish colored limestone which contains some shells and fish and shark teeth. An analysis of the limestone revealed 41.97 per cent of calcium oxide (lime) and 72.94 per cent of lime carbonate. This limestone is well adapted to local use.

On the Atkinson farm the Mobile & Ohio Railroad cuts through the edges of some bluffs which are composed of layers of limestone and intercalated beds of marl. In one of the cuts there is exposed about twelve feet of greenish-gray marl with an overburden of orange-colored sand. The marl is very fossiliferous, containing perfect specimens of gryphae, echnoidea and bacculites.

The bed rock at Houston is concealed by a layer of mantle rock. Samples of the bed-rock have been obtained from wells and cisterns. A sample collected and analyzed by Dr. Hilgard contained the following chemical substances:

Table No. 10.

ANALYSIS OF HOUSTON MARL.

Insoluble matter (micaceous clay)	35.750
Potash	00.681
Soda	00.197
Lime	20.558
Magnesia	1.366
Brown oxide of maganese	0.305
Peroxide of iron	4.190
Alumina	9.475
Iron pyrites	1.743
Carbonic acid	16.760
Organic matter and water	8.774
Total	99.799

According to the above analysis the Houston marl contains 935.8 pounds of carbonate of lime to the ton and 13.62 pounds of potash.

CLARKE COUNTY.

Clarke County contains outcrops of marls belonging to the Calcareous Claiborne and to the Jackson formation and limestone belonging to the Vicksburg formation. The last named forms the bedrock for the southwest portion of the county. The Claiborne crosses the county from east to west near the central part of the county and between its out-crop and that of the Vicksburg lies the Jackson formation. The marls of the Claiborne consist of clay, lime carbonate and sand with smaller amounts of other materials. They are valuable for the local treatment of soils not only on account of the percentage of lime carbonate but also on account of the small amounts of potash and phosphoric acid contained in them.

The analyses of two samples of marl, No. 1 from Parker's Ferry and No. 2 from Falling Creek are contained in the following table:

Table No. 11.

ANALYSES OF CLAIBORNE MARLS FROM CLARKE COUNTY.

Constituent.	No. 1.	No.2.
Insoluble matter	66.347	65.540
Alumina	4.167	2.125
Lime	9.762	15.330
Potash	1.208	.375
Soda	.339	.246
Magnesia	1.442	.599
Brown oxide of maganese	.097	.076
Peroxide of iron	6.405	2.209
Phosphoric acid	.145	.086
Sulphuric acid	.397	.159
Carbonic acid	6.254	10.650
Organic matter and water	3.356	2.579
Total	99.939	99.974

Analyses by Hilgard.

The Jackson formation consists of clays, sands, and marls. The latter contain as a rule higher percentages of lime, potash and phosphoric acid than are contained in the Claiborne marls. The analyses of three samples of these marls, the first from Smith's Spring, the second from Garland's Creek and the third from Shubuta Ferry are given the following table:

Table No. 12.

COMPOSITION OF JACKSON MARLS.

	No. 1.	No. 2.	No. 3.
Insoluble matter	72.783	45.881	52.289
Alumina	2.713	7.751	7.615
Lime	10.560	14.785	19.160
Potash	.639	1.117	.236
Soda	.096	.165	.100
Magnesia	.424	2.476	.355
Brown oxide of maganese	.094	.403	.368
Peroxide of iron	2.058	13.020	....
Phosphoric acid	.468	.327	.353
Sulphuric acid	.257	.566	.583
Carbonic acid	7.967	12.492	15.428
Organic matter and water	2.173	.000	3.611
	100.272	99.883	100.090

Analyses by Hilgard.

One sample of the Claiborne marl contains 24.16 pounds per ton of potash, the other 7.5 pounds, and the one 2.9 pounds of phosphoric acid per ton and the other 1.72 pounds.

Sample No. 1 of the Jackson marls contains 12.78 pounds per ton of potash, sample No. 2 contains 22.34 pounds and sample No. 3 contains 4.72 pounds. Of phosphoric acid No. 1 contains 9.36 pounds, No. 2 contains 6.54 pounds and No. 3 contains 7.06 pounds per ton.

Some notable exposures of Vicksburg limestone occur near Nancy near the Clarke-Wayne County line. The rock is soft and easily cut with a saw. It has been used locally for building blocks in chimneys and foundations. The ease with which it may be crushed renders it of value for use in the liming of lands. The accompanying analyses of two samples exhibit the percentages of lime and other substances contained in it:

Table No. 13.

ANALYSES OF VICKSBURG LIMESTONE FROM NEAR NANCY, CLARKE COUNTY.

Silica (SiO)	7.31	6.77
Alumina (Al_2O_3)	13.61	4.68
Iron oxide (Fe_2O_3)	4.00	2.00
Lime oxide (CaO)	36.62	45.51
Magnesia (MgO)	.29	.64
Volatile matter (CO_2)	35.29	35.40
Sulphur trioxide (SO_3)	2.78	3.00
Moisture	1.00	1.79

Sample No. 1 contains 65.39 per cent of lime carbonate or 1307.8 pounds per ton. Sample No. 2 contains 81.26 per cent of lime carbonate or 1625.2 pounds per ton. Sample No. 1 is from the weathered rock. The other sample while from near the surface of the outcrop is not weathered as much as the former. The rock is soft and easily disintegrated. Blocks for the building of chimneys have been cut from the rock with an ordinary hand saw. The rock could be easily crushed to a degree of fineness suitable for the liming of soils.

CLAY COUNTY.

All of the subsurface of Clay County except a small area about six miles wide in the western part of the county is occupied by a lime-bearing formation, the Selma chalk, which is the bed-rock for the greater part of the county. This chalk gives rise to black calcareous soils. In many places the mantle rock has been removed by erosion and the chalk lies exposed at the surface. As a rule the chalk in the the western part of the county contains the highest per cent of lime carbonate, and is, on that account, very suitable for liming purposes.

Selma at West Point.—In the clay pit belonging to the West Point Brick Manufacturing Company, at West Point, the clay rests upon the surface of a stratum of the Selma chalk. On the weathered surface the chalk is white but below the weathered surface it is blue in color. The chalk which is exposed in the bottom of the pit contains the impressions of many shells. The following table gives the analysis of a sample of the weathered chalk:

Table No. 14.

ANALYSIS OF SELMA CHALK FROM WEST POINT.

Moisture (H_2O)	2.75
Volatile matter (CO_2, etc.)	22.61
Silicon dioxide (SiO_2)	32.81
Iron oxide (Fe_2O_3)	4.65
Aluminum oxide (Al_2O_3)	11.15
Calcium oxide (CaO)	22.69
Magnesium oxide (MgO)	1.53
Sulphur trioxide (SO_3)	1.55
Total	99.74

In this particular outcrop the percentage of lime is small because the sample comes from near the lowermost horizon of the Selma chalk. The outcrops in the western part of the county contain a higher per cent of lime and are more suitable for liming purposes.

HINDS COUNTY.

The calcareous formations of Hinds County are the Jackson marls and the Vicksburg limestone. The former occupies the surface and the subsurface in the northwestern part of the county and the latter borders the former in a narrow belt to the south. Both contain shell marls and the latter contains limestone of sufficient purity to be used for agricultural purposes. The Jackson marls outcrop along the banks of Pearl River from Jackson to a point opposite Canton; the outcrop at the Jackson bridge across Pearl River, shows blue and yellow sands containing shells. Another outcrop occurs on Town Creek south of Jackson.

One sample of the Jackson clay marl contains 14.93 per cent of calcium oxide (CaO) and 26.57 per cent of calcium carbonate. Another sample contained 11.40 per cent of calcium oxide and 20.29 per cent of calcium carbonate. One sample of the Vicksburg limestone contains 50.55 per cent of calcium oxide (quicklime) and 90.26 per cent of calcium carbonate or 1805.2 pounds per ton. Another sample contains 43.932 per cent of lime and 78.45 per cent of lime carbonate or 1569 pounds per ton of the latter. It also contains 0.224 per cent of phosphoric acid or 4.48 pounds per ton and 0.611 per cent or 12.22 pounds per ton of potash.

Some of the upland sandy and silt soils of Hinds County are acid and would be greatly benefitted by an application of ground limestone. The shell marls and the soft limestones of the Vicksburg formation are available and are suitable for this purpose. Some of the soils of the county could be made suitable for the growing of alfalfa by an application of ground limestone.

Byram.—About 30 feet of marl are exposed on the west bank of Pearl River near the Wagon bridge at Byram. An almost continuous exposure extends up and down the river for a distance of about 3 miles. This marl is intercalated with beds of limestone of varying degrees of hardness. The following are analyses of samples of the marl, No. 1 by Hilgard and No. 2 by Hand:

Table No. 15.

No. 1.	Per Cent.
Insoluble matter (chiefly sand)	12.308
Potash	0.611
Soda	.179
Lime	43.932
Magnesia	1.658
Peroxide of iron and Alumina	2.696
Iron pyrites	1.266
Phosphoric acid	0.224
Carbonic acid and loss	34.720
Water and organic matter	2.396
Total	100.00

No. 2.	Per Cent.
Silica (SiO2)	26.42
Alumina (Al_2O_3)	8.25
Ferric oxide (Fe_2O_3)	5.20
Lime (CaO_2)	27.77
Magnesia (MgO)	1.44
Volatile matter	26.00
Sulphur trioxide (SO_3)	2.00
Moisture	3.00
Total	100.08

The amount of potash and phosphoric acid was not determined in the case of sample No. 2. Analysis No. 1 exhibits a sufficient quantity of each of these substances to make the marl of value aside from the lime content. The marl is soft and easily dug. It would disintegrate rapidly when placed on the land and would not require crushing, for the softer strata at least. Transportation facilities are good at this point, either by rail or river.

A sample of the limestone from this point was analyzed with the following results:

Table No. 16.

ANALYSIS OF VICKSBURG LIMESTONE FROM BYRAM.

Silica (SiO_2)	2.28
Alumina (Al_2O_3)	2.42
Ferric oxide (Fe_2O_3)	2.19
Lime (CaO)	50.55
Magnesia (MgO)	1.40
Volatile matter (CO_2)	40.87
Sulphur trioxide (SO_3)	.30
Moisture	.31

The limestone in the west bank of the Pearl River at Byram forms a broad shelf swept clear of marl. Marl beds occur both above and below this layer of limestone. There is an inexhaustible supply of marl and limestone in the Byram outcrops. There are several outcrops of limestone north and west of Byram.

Table No. 16a.

Analysis of Soft Vicksburg Limestone 1 mile west of Elton, on Jackson and Terry road. Total thickness here 10 feet. Samples collected by E. N. Lowe, July 3, 1916.

AVERAGE RESULTS OF TWO ANALYSES:

	Per Cent
Moisture	1.25
Lime (CaO)	50.19
Calcium Carbonate, $CaCO_3$, (calculated)	89.56

On the Cooper's Wells road about seven miles southwest of Jackson, the public road cuts through and exposes a layer of Vicksburg limestone. Many large blocks having a diameter of from 3 to 4 feet are exposed on the road side.

Moody's Branch.—Marl outcrops in Moody's Branch in the northeast part of Jackson; one of the exposures is on the R. E. Kennington place. An analysis of a sample by Hilgard is given below:

Table No. 17.

Insoluble matter (white clay and fine silica)	.37.400
Potash	.445
Soda	.208
Lime	28.821
Magnesia	1.407
Peroxide of iron, and alumina	5.133
Phosphoric acid	.256
Carbonic acid, and loss	23.084
Water	3.246
Total	100.000

JASPER COUNTY.

The Jackson calcareous clays and the Vicksburg limestone form a portion of the sub-surface and the surface of Jasper County and contribute to its soils. The larger part of these calcareous soils are to be found east of a line joining Baxter with Vossburg. Other areas occur west and southwest of Montrose. Some outcrops of the Jackson and of the Vicksburg are found in these localities. There is an outcrop of the Vicksburg limestone about three miles southwest of Paulding. In physical properties it is very like that of the Robinson quarry near Brandon in Rankin County. There can be no doubt that the marls and limestones are suitable for local use in the liming of soils.

Table No. 17a.

Analysis of Limestone from Longino Property 2 miles northwest of Bay Springs. Collected by E. N. Lowe, April, 1916.

AVERAGE RESULTS OF THREE ANALYSES:

	Per Cent
Moisture	0.96
Lime (CaO)	49.98
Calcium Carbonate, $CaCO_3$ (calculated)	89.56

Table No. 17b.

Analysis of Limestone from Hill 3-4 mile east of Heidelberg. Collected by E. N. Lowe, April 22, 1916.

AVERAGE RESULTS OF THREE ANALYSES:

	Per Cent
Moisture	1.06
Lime (CaO)	50.37
Calcium Carbonate, $CaCO_3$, (calculated)	89.56

Table No. 17c.

Analysis of Limestone 1-3 mile east of Heidelberg on N. O. & N. E. Railroad. Collected by E. N. Lowe, April 22, 1916.

AVERAGE RESULTS OF TWO ANALYSES:

	Per Cent
Moisture	0.975
Lime (CaO)	50.715
Calcium Carbonate, $CaCO_3$, (calculated)	90.50

The southern part of the county is occupied by sandy loam and clay loam soils which are in most instances deficient in lime and even on the uplands are acid. These soils would be greatly benefited by the application of ground limestone. The clay soils would be improved in texture since lime has the power of rendering the soil more pervious to water and air. It prevents the soil from packing, baking and cracking. It makes cultivation easier and furnishes proper moisture and air conditions for the bacteria of the soil.

Calcium is one of the essential elements in plant growth and lime or ground limestone supplies this element to the soil. Lime also corrects the acid condition of soils, a condition detrimental to the growth of many crops. Lime not only supplies calcium for the use of growing crops but also for the use of bacteria and other micro-organisms of the soil. These not only need calcium for their bodily wants but they cannot thrive under acid conditions, and lime is necessary to correct this acidity.

KEMPER COUNTY.

A small area in the northeastern part of Kemper County is occupied by the Selma chalk as a bed-rock formation. The Ripley formation also outcrops in a small area to the south of the Selma and the Clayton division of the Eocene borders the latter on the southwest. All of these formations are lime-bearing but the Selma chalk contains the highest per cent of lime. The later probably attains its greatest thickness and highest purity in this part of the State; the samples so far collected do not exhibit as high a per cent of lime carbonate as some of those from other counties. The composition of three samples of the Selma chalk from Kemper County is given in the following table:

Table No. 18.

ANALYSIS OF SELMA CHALK FROM KEMPER COUNTY.

W. S. McNeil, Analyst.

	Sample 1.	Sample 2.	Sample 3.
Silica (Si_2O)	16.48	10.60	20.00
Alumina (Al_2O_3) and iron oxide (Fe_2O_3)	6.97	5.90	8.92
Lime carbonate ($CaCO_3$)	74.34	82.47	68.91
Magnesium carbonate ($MgCO_3$)	0.67	Tr.	Tr.
Water	0.67	0.82	1.06

These three samples contain an average of 1504.8 pounds per ton of lime carbonate and the amount of lime carbonate in one of the samples is 1649.4 pounds per ton.

LEE COUNTY.

The entire subsurface of Lee County is occupied by the Selma chalk. Although in general the surface of the chalk is covered with a thin mantle of other rocks still there are numerous points where it reaches the surface, particularly along the banks of the creeks or the borders of the larger valleys. The presence of the outcrop is usually indicated by plum thickets and dense growths of mellilotus.

Limestone Near Tupelo.—At Tupelo the surface of the limestone is covered with mantle rock varying in thickness from 10 to 25 feet. About one mile west of Tupelo the Selma chalk is exposed at the surface. The amount of lime carbonate contained in a sample of the of the rock is 75 per cent. This sample was taken from the white weathered chalk. The unweathered rock doubtless contains a higher per cent of calcium carbonate. The following is the analysis of the sample taken from this point:

Table No. 19.

ANALYSIS OF SELMA CHALK ONE MILE WEST OF TUPELO.

Silica (SiO_2)	14.84
Alumina (Al_2O_3)	15.59
Iron oxide (Fe_2O_3)	4.50
Lime (CaO)	32.98
Magnesia (MgO)	0.41
Volatile matter (CO_2)	27.10
Sulphur trioxide (SO_3)	3.30
Moisture	1.08

Table No. 19a.

Analysis of Limestone from land of G. W. Ritter, 1-2 mile east of Belden. Collected by E. N. Lowe, April 12, 1916.

AVERAGE RESULTS OF THREE ANALYSES:

	Per Cent
Moisture	1.00
Lime (CaO)	44.80
Calcium Carbonate, $CaCO_3$, (calculated)	83.27

On the road to Pontotoc two and one-half miles west of Tupelo there are some exposures of Selma chalk. There are also some outcrops about the same distance south of Tupelo. A sample from the latter point contains about 78 per cent of lime carbonate. The analysis of the sample is given in the following table:

Table No. 20.

ANALYSIS OF SELMA LIMESTONE SOUTH OF TUPELO.

Silica (SiO_2)	22.76
Alumina (Al_2O_3)	4.56
Iron oxide (Fe_2O_3)	6.46
Lime (CaO)	34.31
Magnesia (MgO)	0.05
Volatile matter (CO_2)	28.25
Sulphur trioxide (SO_3)	0.43
Moisture	2.10

Table No. 20a.

Analyses of Limestone from place of O. F. Vaughan, 2 1-2 miles west of Shannon. Collected by E. N. Lowe, April, 1916.

AVERAGE RESULTS OF THREE ANALYSES:

	Per Cent
Moisture	1.45
Lime (CaO)	44.56
Calcium Carbonate, $CaCO_3$, (calculated)	79.52

Guntown.—In a cut on the Mobile & Ohio railroad just north of the station at Guntown there is an outcrop of shell marl. The marl has a blue color and contains a layer of shell rock from 8 inches to 2 feet thick which is much more resistant than the remainder of the rock and projects from the face of the cut. There is something like ten feet of the marl exposed. Below the shell rock there is a layer of green sand. Mellilotus and Johnson grass grow luxuriantly on the outcrop. The blue marl and the shell rock are suitable for liming.

Baldwyn.—About two blocks south of the public school building at Baldwyn there is an exposure of Selma chalk on the top and sides of a small hill. The marly chalk contains considerable quantities of shells of ostrea, gryphea and exogyra, the latter being of large size. The face of the outcrop is partly covered with plum thickets and growths of mellilotus. A sample of the limestone contains 29.74 per cent of lime, and 52.94 per cent or 1058.8 lbs. per ton of calcium carbonate, 0.51 per cent or 10.2 lbs. of phosphoric acid and 0.3080375 per cent or 6.16 lbs. of potash per ton.

LOWNDES COUNTY.

Lowndes County is well supplied with limestone suitable for the liming of soils. The entire subsurface and parts of the surface of the county west of the Tombigbee River is occupied by the Selma chalk, a lime-bearing formation. The chalk varies from place to place in the per cent of lime and as a rule the chalk in the western part of the county contains the highest per cent of lime. The rock in all places is of such a low degree of hardness that the expense of crushing it to a sufficient degree of fineness for agricultural application would not be excessive. There are many areas of sandy soils in the county that would be benefitted by a treatment of lime, this is particularly true of the soils east of the Tombigbee River. The chalk also contains small quantities of potassium and phosphorus which are beneficial to the soil.

The sample of limestone of a soft variety from Plymouth Bluff, northeast of Columbus on the Tombigbee River, contains 30.18 per cent of lime and 53.72 per cent of calcium carbonate (limestone), or 1074.4 pounds per ton of the latter. This sample also contains 0.195 per cent or 3.9 pounds per ton of phosphoric acid and 0.207475 per cent or 4.15 pounds per ton of potash. Another sample from a harder layer lying below the soft layer contains 24.4 per cent of lime and 43.43 per cent of lime carbonate, or 868.6 pounds per ton. This sample contains 3.8 pounds of phosphoric acid and 3.18 pounds of potash per ton. A sample of chalk from Crawford contains 39.58 per cent of lime and 70.45 per cent of lime carbonate or 1409 pounds of the latter per ton. It also contains 7.45 pounds of phosphoric acid and 6.27 pounds of potash per ton. Another sample from the same locality but not from the same outcrop, 46.28 per cent of lime and 82.37 per cent of lime carbonate, or 1647.4 pounds per ton. It contains 5.4 pounds of phosphoric acid and 2.7 pounds of potash per ton.

Small outcrops of Selma chalk occur widely distributed in all that part of the county west of the Tombigbee River. There are many places where there is no overburden and limestone may be quarried without the expense of surface stripping.

Artesia and Vicinity.—Exposures of limestone occupy the south and east bluffs of a small branch of Catalpa Creek which circles Artesia on the west and north. An outcrop begins at the coaling station on the Mobile & Ohio Railroad and extends north for nearly two miles on the east bluff of this creek and on the east side of the railroad. Numerous outcrops also occur along the banks of Red Bud Creek south of Artesia. About two hundred yards west of the coaling station an excavation was made in the chalk for a dipping vat. The upper portion of the vat to a depth of two feet was cut in the weathered white chalk, the remaining five feet in the blue unweathered chalk. The chalk contains a number of fossil shells. It is soft and its disintegration is so rapid that there is no necessity of its being crushed finer than a maximum diameter of two or three inches before being applied for liming purposes. The total vertical thickness of the exposure is about twenty-five feet. The band of blue chalk at the base gradually grades into the white or yellowish tinted layer of the surface. In the upper surface the chalk is fissile and readily separated into thin blocks. It appears more massive in the lower layers. Joint planes are not numerous but are present. Mellilotus and Bermuda exhibit a rank growth near the outcrop. The railroad well record shows a total thickness of 350 feet of chalk.

Crawford and Vicinity.—Numerous outcrops of limestone occur west of Crawford on the branches of Brooks Creek, also east of Crawford on the branches of McCower's Creek. In Crawford by the side of the Mobile & Ohio Railroad, a few rods north of the station, the chalk appears at the surface. One mile west of the station there are outcrops which extend westward for more than a mile in almost unbroken continuity. Fossil species of ostrea, gryphea and exogyra are exceedingly abundant, the entire surface in some places being covered with them. There are also some bones of marine reptiles found occasionally. An analysis of a sample of the limestone from the land of Mr. J. B. Brooks, near Crawford, exhibited the following constituents:

Table No. 21.

ANALYSIS OF SELMA LIMESTONE FROM CRAWFORD.

Silica (SiO)	8.88
Alumina (Al_2O_3)	5.94
Iron oxide (Fe_2O_3)	5.94
Calcium carbonate (CaCO)	79.73
Magnesia (MgO)	1.22
Loss	1.88

This analysis shows a sufficiently high per cent of carbonate of lime to be useful for liming purposes. It is probable that the rock taken at a slightly increased depth would contain a higher per cent of lime carbonate. A sample taken from the outcrop north of Crawford contains 70.45 per cent of carbonate of lime, or 1409 pounds per ton. It contains 0.3725 per cent or 7.45 pounds of phosphoric acid and 0.31625 per cent of potash or 6.27 pounds per ton. A sample of the rock from west of Crawford contains 82.37 per cent of carbonate of lime, 1647.4 pounds per ton; 0.27 per cent, 5.4 pounds per ton of phosphoric acid and 0.1351 per cent of potash, or 2.7 pounds per ton.

Table No. 21a.

Analyses of Limestone from land of P. W. Maer, Artesia. Collected one sample by E. N. Lowe, one by P. E. Mathews.

AVERAGE RESULTS OF TWO ANALYSES:

	Per Cent
Moisture	1.09
Lime (CaO)	46.69
Calcium Carbonate, $CaCO_3$, (calculated)	82.66

Plymouth Bluff.—On the Tombigbee River about five miles north of Columbus there is a high river bluff. At the base of the bluff there is a very sandy clay of bluish color. The thickness of the layer exposed is about ten feet. It is capped by a layer of sandstone of fissile nature, having a thickness of from one to two feet and containing the impressions of many large shells of gryphea, ammonites and inocerami. This layer of sandstone projects out in the form of a ledge or shelf which has a width of thirty feet in some places. Beneath the sandstone the clay has been cut out by the current forming small caves. Above the sandstone layer there are three or four feet of sandy clay. This is followed above by about twenty-five feet of sand which is succeeded above by from six to ten feet of sandy marl. This upper layer marks the transition from the Eutaw to the Selma. The marly layer contains shells and fragments of bones.

A sample of the marl from this locality which is soft in nature contains 30.18 per cent of lime and 53.72 per cent of lime carbonate or 1074.4 pounds per ton of the latter. It also contains 0.195 per cent or 3.9 pounds of phosphoric acid and 0.207475 per cent or 4.15 pounds per ton of potash. Another sample from a harder layer of marl lying below the soft layer contains 24.4 per cent of lime and 43.43 per cent of lime carbonate, or 868.6 pounds per ton. The sample also contains 0.19 per cent of 3.8 pounds of phosphoric acid and 0.159225 per cent or 3.18 pounds per ton of potash.

McIntyre and Vicinity.—On the banks of Matly Slough between Bentoak and McIntyre, along the M. & O. Railroad one-half mile east of McIntyre and southeast of McIntyre there are outcrops of chalk. Also at Evans store and south and southeast of the same. Also at Kilgo church on the south banks of Catalpa Creek.

Waverly Bluff.—A greenish-gray micaceous sand forms the bluffs of the Tombigbee River at this point. The sand is fossiliferous but contains only a small amount of lime as the fossils are mostly impressions rather than shells. A sample of the sand was analyzed by Dr. Hilgard, (see Geology of Mississippi, p. 96) with the following results:

Table No. 22.

SAND FROM WAVERLY BLUFF.

Micaceous sand	88.702
Potash	0.204
Soda	0.190
Lime	1.351
Magnesia	0.723
Peroxide of iron and alumina	5.598
Phosphoric acid	0.328
Sulphuric acid	0.013
Carbonic acid	0.472
Water	2.308
Total	99.884

This sand marl contains only 61.4 pounds of lime carbonate to the ton, 4.08 pounds of potash and 6.76 pounds of phosphoric acid. Its lime content is much lower than that of the marl at Plymouth Bluff and although its potash and phosphoric acid content is greater it is not as valuable for agricultural purposes as the former.

MARION COUNTY.

There are some outcrops of a silicious clay marl in this county which contain some fertilizing constituents. Tbe percentage of lime is small and they cannot be recommended for liming purposes.

Barnes Bluff.—This bluff is on the Pearl River northwest of Columbia and rises more than 100 feet above the river bed. Its lower portion is composed of Grand Gulf strata and the upper portion of Lafayette. The Grand Gulf is for the most part a silicious clay but contains a stratum of yellow clay containing nodules of lime carbonate. The following is the analysis of a sample of the clay: (See Hilgard's Geology of Mississippi, p. 180).

Table No. 23.

ANALYSIS OF BARNES BLUFF MARL-CLAY.

Insoluble matter (clay and silex)	77.438
Potash	0.709
Soda	0.101
Lime	4.800
Magnesia	1.248
Brown oxide of maganese	0.310
Peroxide of iron	2.989
Alumina	6.449
Phosphoric acid	0.111
Sulphuric acid	trace
Carbonic acid	3.372
Water	2.554
	100.197

Burnetts Bluff.—This is another bluff on Pearl River composed of the silicious clays of the Grand Gulf formation. A stratum of greenish clay loam contains the following constituents according to an analysis made by Hilgard. (See Geology of Mississippi, p. 181).

Table No. 24.

ANALYSIS OF GREEN LOAM FROM BURNETT'S BLUFF.

Insoluble matter (clay and silex)	83.691
Potash	0.827
Soda	0.268
Lime	0.793
Magnesia	1.053
Brown oxide of maganese	0.223
Peroxide of iron	.4.394
Alumina	8.347
Phosphoric acid	0.148
Sulphuric acid	0.022
	99.761

MONROE COUNTY.

Practically all of Monroe County west of the Tombigbee River is occupied by the outcrop of the Selma chalk though its surface is here and there concealed by ridges of more recent formations. However the Selma is the principal calcareous formation of the county. The composition of the limestone is doubtless similar to that around Okolona and is suitable for agricultural purposes. A sample of limestone from an outcrop west of Aberdeen contains 42.12 per cent of calcium oxide and 74.97 per cent of calcium carbonate. In the western part of the county the chalk contains a higher per cent of lime than the above sample which is from the lowermost horizon of the Selma chalk.

The soils of Monroe County east of the Tombigbee River are generally deficient in lime as the rocks from which the soils are derived are deficient. These soils are derived from sands and clays, the clays as a rule containing the higher per cent of lime. But even in the clays the amount of lime is small as shown by the following analyses of two of them:

PLATE III.

FIG. 1. A Valley Plain Carved Out of the Selma Chalk. The Limestone Bluff in the Foreground Covered with Plum Thickets. (Photo by Louis Roark).

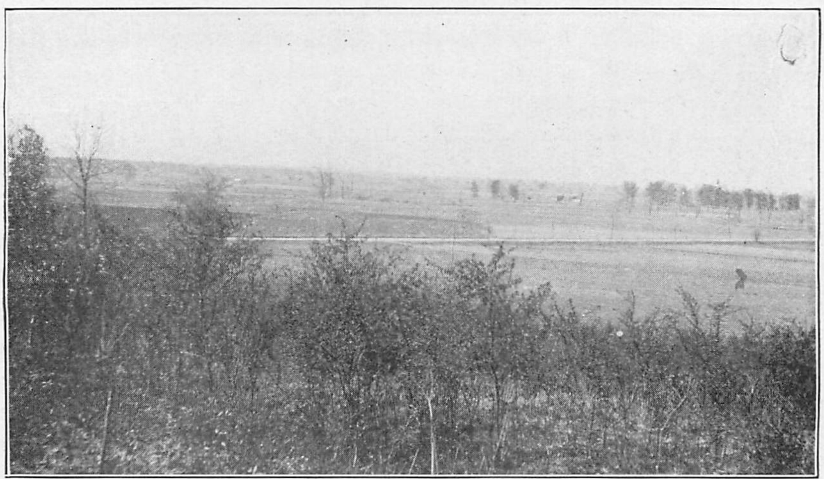


FIG. 2. A View of the Same Valley from Another Point. Limestone Outcrop in the Foreground. Sand Creek Valley, Oktibbeha County. (Photo by Roark).

Table No. 25.

ANALYSES OF MONROE COUNTY CLAYS.

Constituent.	Aberdeen Per Cent.	Amory Per Cent.
Moisture (H_2O)	4.95	5.20
Volatile matter (CO_2, etc.)	4.92	5.10
Silicon dioxide (SiO_2)	71.13	71.04
Iron oxide (Fe_2O_3)	7.75	7.92
Aluminum oxide (Al_2O_3)	9.12	9.27
Calcium oxide (CaO)	.42	.87
Magnesium oxide (MgO)	.63	.31
Sulphur trioxide (SO_3)	.08	tr.
Total	99.00	99.71

Both of these clays contain less than one per cent of lime and the soils which are derived from them must contain even less.

NOXUBEE COUNTY.

The greater part of the surface and sub-surface of Noxubee County are occupied by the lime-bearing Selma chalk as a bed-rock formation. Though the surface of the chalk is concealed largely by mantle rock there are numerous exposures where it may be quarried without the removal of much over-burden. With the exception of a few resistant layers in the chalk in the eastern part of the county it is a soft rock which may be easily crushed and which disintegrates rapidly when exposed to the weathering agents. It is suitable for the liming of land because of its softness, its high lime content and the rapidity with which it disintegrates.

Eight samples of chalk were collected from different parts of the county and the per cent of lime carbonate determined varied from 73.62 per cent (1472.4 pounds per ton) to 98.36 per cent (1967.2 pounds per ton). One of these samples contained 0.36 per cent or 7.2 pounds per ton of phosphoric acid and 0.275025 per cent or 5.5 pounds per ton of potash. Another sample contains 5.45 per cent or 5.45 pounds per ton of phosphoric acid and 0.2725 per cent of potash or 3.96 pounds per ton.

In the western part of Noxubee County there is a belt of clay soils belonging to the Flatwoods belt. These soils are deficient in lime and are acid in many places. Not only may the productivity but also the texture of these soils be improved by the application of lime. Because of the sticky nature of these soils they are very generally thought to contain lime but this view is erroneous. The tenacity is due to the fineness of the grain of the silica of which the clay contains a high per cent. The sandy upland soils lying west of the Flatwoods contain many areas which are acid and which will be greatly benefitted by an application of ground limestone, this form being preferable to the more caustic quicklime.

Macon.—In the vicinity of Macon the Selma lies covered for the most part by the residual clay formed from its disintegration. At the brick-yard the removal of this clay has exposed the limestone. Erosion has uncovered it on the Prairie Point road a few miles from Macon. Some thirty or forty feet of the rock is exposed in a bluff on the Noxubee River at the mouth of Macon Creek only a short distance from Macon. The average amount of calcium carbonate is about 80%. Some particular layers contain as high as 98% of lime carbonate. The latter are especially valuable for the manufacture of lime and the liming of lands. The following analyses are of samples of limestone from the vicinity of Macon:

Table No. 26.

ANALYSES OF SELMA LIMESTONE FROM MACON.

	1.	2.
Silica (SiO_2)	9.09	13.03
Alumina (Al_2O_3)	7.47	7.43
Iron oxide (Fe_2O_3)	7.47	7.43
Lime carbonate ($CaCO_3$)	80.99	76.71
Magnesium carbonate ($MgCO_3$)	.00	.36
Water	1.08	.95
Sulphur trioxide (SO_3)	0.00	.64

Table No. 27.

ANALYSIS OF SELMA LIMESTONE FROM 3 MILES NORTH OF MACON.

Silica (SiO_2)	8.52
Alumina (Al_2O_3)	6.60
Iron oxide (Fe_2O_3)	6.60
Lime carbonate ($CaCO_3$)	83.88
Magnesium carbonate ($MgCO_3$)	.00
Water	1.00

Three other samples from Macon Bluff contains the following per cents of lime carbonates: No. 1, 77.67; No. 2, 73.76; No. 3, 73.62.

Table No. 27a.

Analyses of Limestone from Bluff of Noxubee River at Macon. Collected by E. N. Lowe, April, 1916.

AVERAGE RESULTS OF THREE ANALYSES:

	Per Cent
Moisture	1.28
Lime (CaO)	42.94
Calcium Carbonate, $CaCO_3$, (calculated)	76.68

Table No. 28.

ANALYSIS OF SELMA LIMESTONE FROM PRAIRIE ROCK.

Silica (SiO_2)	1.13
Alumina (Al_2O_3)	.68
Iron oxide (Fe_2O_3)	.68
Lime carbonate ($CaCO_3$)	98.36
Magnesium carbonate ($MgCO_3$)	Tr.
Water	.40

Brooksville.—Limestone forms the bed rock at no great distance from the surface in the neighborhood of Brooksville. West of Brooksville for three miles there are numerous outcrops of Selma chalk. The land is rolling and the soils formed on a yellow residual clay for the most part. The exposures of limestone contain the shells of ostrea, gryphea and exogyra.

One sample of limestone from this locality contains 44.50 per cent of calcium oxide and 79.21 per cent of calcium carbonate or 1584.2 lbs. per ton of the latter. It also contains .36 per cent or 7.2 lbs. per ton of phosphoric acid and 0.275025 per cent or 5.50 lbs. per ton of potash. Another sample contains 43.96 per cent of calcium oxide and 78.25 per cent of calcium carbonate.

Table No. 28a.

Analyses of Limestone from Cut on M. & O. R. R., three miles north of Shuqualak. Collected by E. N. Lowe, April, 1916.

AVERAGE RESULTS OF THREE ANALYSES:

	Per Cent
Moisture	.74
Lime (CaO)	45.09
Calcium Carbonate, $CaCO_3$, (calculated)	76.30

OKTIBBEHA COUNTY.

The principal lime-bearing formation in Oktibbeha County is the Selma chalk which forms the bed-rock of the eastern part of the county. The chalk in some of its outcrops contains a high per cent of lime carbonate; one sample containing 1892 pounds of lime carbonate to the ton. The maximum thickness of the formation in Oktibbeha County is about eight hundred feet. The Starkville deep well passes through 749 feet of chalk and it occurs at least fifty feet higher in the hills around Starkville. The thickness of the formation on the eastern border of the county near Mayhew is 350 feet; at Muldrow, in the northeastern part of the county, it has a thickness of 250 feet which is probably near the minimum for the county. Between Muldrow and Tibbee Creek the thickness of the chalk is doubtless less but there is no record. Near the northern border, south of Cedar Bluff, the thickness is about 300 feet.

The physical character of the chalk varies in different horizons, and to a limited extent in the same horizon. In the main, however, it exhibits considerable uniformity of structure and material. The upper and lower strata are distinctly arenaceous and in some places argillaceous. The middle stratum is more nearly composed of calcium carbonate which is in the shells (mostly microscopic) with small amounts of sand and clay. The color of the chalk on surfaces which have long been exposed to the weather is white or yellowish white. On freshly exposed surfaces it is light blue. The bluish tint is lost by the oxidation of the coloring substances and the chalk becomes white. Proof of this change of color is found in nearly every outcrop. The lower or most recently exposed part of the outcrop has a blue color which gradually fades out above passing into white by a gradual transition. There is no clearly defined and regular line between the two colors such as would be present if the difference of color were due to stratification. Crevices which pass from the surface through the white into the blue chalk have in the latter whitened walls several inches in thickness. The explanation of this fact is that the surface water which flows through these crevices carries oxygen which effects the oxidation of the coloring matter. These phenomena may be noted in the outcrops of chalk along the line of the Illinois Central Railroad in the eastern part of Starkville. The same facts may be noted in outcrops in other parts of the county.

Overlying the Selma chalk in a few places in the county there is a micaceous green-sand marl which is thought to belong to the Ripley formation. These outliers of the Ripley occupy high points on the Selma Chalk divide between the Sand Creek and the Trim Cane Creek water courses. One of the outcrops is located on the Mayhew road about two miles east of Starkville. At this point about twenty feet of bluish marl underlies about ten or fifteen feet of yellowish micaceous marl. This marl contains lime, potash and phosphoric acid. Other outcrops of the Ripley have been found in the Thompson Hills north of Starkville. One of these outcrops is on the Osborn road about six miles northeast of Starkville. At the base of the outcrop about twenty-five feet of bluish marl is exposed. It is micaceous and contains green sand. The upper part of the outcrop consists of about twelve feet of yellowish marl containing mica and green sand. The entire outcrop contains many large shells.

A green sand marl near the upper horizon of the Selma chalk in Oktibbeha County contains phosphatic nodules and thin layers of phosphatic rock. The marl has been found on the highest stream divides in the western part of the Selma outcrop. One sample of the marl contained 2.71 per cent of phosphoric acid or 54.2 pounds per ton. The fossil casts of the marl contained 20.60 per cent of phosphoric acid or 412 pounds to the ton. The phosphatic nodules (coprolites) contain 22.90 per cent of phosphoric acid or 458 pounds per ton. A few thin layers of crinoidal limestone occur in a few outcrops. A sample of this limestone contains 2.71 per cent of phosphoric acid or 45.6 pounds per ton. In some localities the amount of nodules and fossil casts in the chalk is sufficient to bring the average per cent of phosphoric acid for the whole marl up to 4 per cent or 80 pounds per ton.

The beneficial effect produced by these phosphates upon the soils may be noted anywhere along the line of outcrop mentioned above. All of the valleys of the small streams or runs which head in or near the marl horizon have extremely fertile soils. These soils will yield good crops year after year with apparently no decrease in fertility. The reason for this fertility is that the marl being washed down from the slopes at the head of the stream and spread over the surface of the valley by the flood waters renews the soil periodically.

Table No. 28b.

Analyses of Limestone from I. C. R. R. Cut, one mile southwest of Osborne. Collected by E. N. Lowe, April, 1916.

AVERAGE RESULTS OF THREE ANALYSES:

	Per Cent
Moisture	1.20
Lime (CaO)	44.56
Calcium Carbonate, $CaCO_3$, (calculated)	79.51

Table No. 28c.

Analyses of Limestone from I. C. R. R. Cut, 3-4 mile southwest of Osborne. Collected by E. N. Lowe, April, 1916.

AVERAGE RESULTS OF THREE ANALYSES:

	Per Cent
Moisture	1.34
Lime (CaCO)	41.99
Calcium Carbonate, $CaCO_3$, (calculated)	79.51

Occasionally along the line of outcrop a cultivated field is found which has derived its soil largely from the marl itself. Such a field occurs on the farm of Dr. A. H. Rice near Octoc. The field is situated on the crest of the divide, and although the soil is thin, so thin that the plow will in places turn up fresh marl, yet the field is remarkable for its productiveness—a field where Dr. Rice says he has often taken people to show them how a field on the top of a hill will produce better crops than their valleys. The marked fertility of many of the fields of the divide is directly due to the marl bed.

Another beneficial effect of the marl noted in many places is its power to check and prevent erosion. Where the marl bed occurs at the head of a run the slopes are rarely precipitous but are very gently inclined. The soil of the run is so fertile that vegetation grows exceedingly rank and checks erosion in the run. This vegetation often remains green long after that in less favored spots has become brown and dry. Even upon the almost barren surface of the marl the Mellilotus grows luxuriantly. In time the accumulation of its stems and leaves produces, in connection with the marl disintegrated by its roots or washed from a higher part of the outcrop, a soil in which other forms of vegetation soon attain a stand and the Mellilotus is driven out by weeds and grasses. Thus Nature prepares a fertile soil from the barren rock and points the way to its profitable utilization by the farmer.

Agricultural College and Vicinity.—The eastern part of Oktibbeha County is occupied by the outcrop of the Selma chalk except in such places as it is concealed by mantle rock. The thickness of the Selma chalk in the vicinity is about 800 feet. West of Starkville it is concealed by Tertiary formations. The Selma chalk-marl of the county varies much in the amount of lime carbonate as will be seen by the following analyses which were made under the direction of Dr. W. F. Hand, State Chemist:

Table No. 29.

ANALYSIS OF SELMA LIMESTONE FROM OKTIBBEHA COUNTY.

Hand, State Chemist.

Silica (SiO_2)	2.89	2.33	3.03	2.55
Alumina (Al_2O_3)	1.53	1.72	1.92	1.96
Iron oxide (Fe_2O_3)	1.53	1.72	1.92	1.96
Lime carbonate ($CaCO_3$)	94.10	94.35	93.60	94.07
Magnesium carbonate ($MgCO_3$)	1.84	1.82	1.64	2.12
Water	.36	.44	.42	.52

The above samples all exhibit a high per cent of lime carbonate. Those in the following table range much lower in the per cent of lime carbonate, varying from about 39 to 71 per cent. The average per cent of lime carbonate in the above samples is 94.03 per cent or 1880.6 lbs. per ton of rock.

Plate IV.

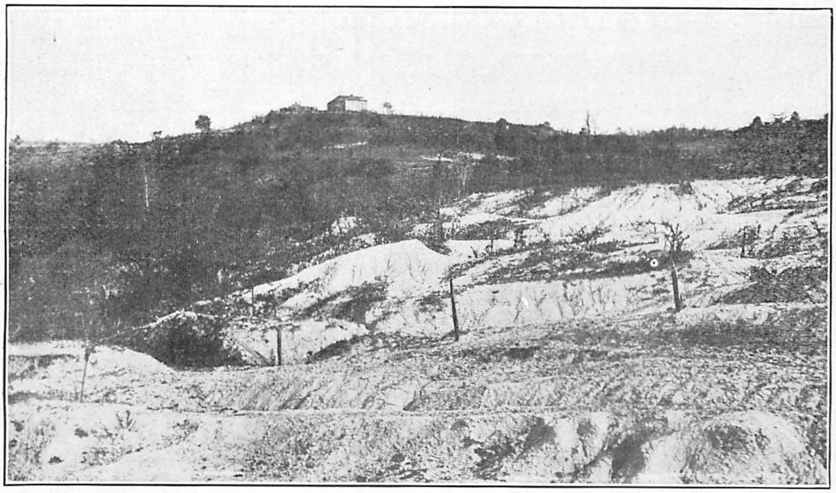


Figure 1. Typical Exposure of Selma Chalk, Sand Creek Bluff, One Mile East of A. & M. College. Photo by E. N. Lowe.

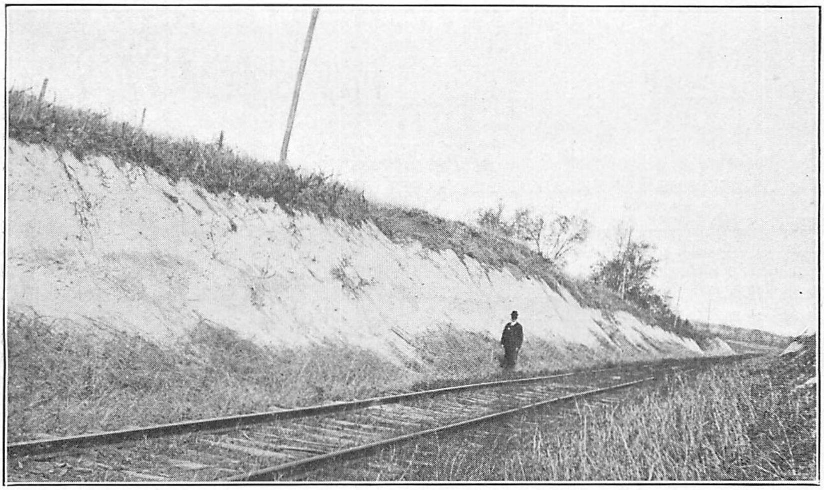


Figure 2. Exposure of Selma Chalk in Cut of Houston Branch of M. & O. R. R., 1½ Miles West of Okolona. One of the State Lime Crushing Plants is Established Here. Photo by E. N. Lowe.

Table No. 29a.

Analyses of Limestone from Sand Creek Bluff, one mile east of A. & M. College. Collected by E. N. Lowe, April 15, 1916.

AVERAGE RESULTS OF THREE ANALYSES:

	Per Cent
Moisture	1.69
Lime (CaO)	36.89
Calcium Carbonate, $CaCO_3$, (calculated)	65.84

Table No. 29b.

Analyses of Limestone from Mayhew Road, 1-2 mile northeast of A. & M. College. Collected by E. N. Lowe, April 15, 1916.

AVERAGE RESULTS OF THREE ANALYSES:

	Per Cent
Moisture	1.65
Lime (CaO)	35.63
Calcium Carbonate, $CaCO_3$, (calculated)	63.58

Table No. 29c.

Analyses of Limestone from Cut on M. & O. R. R., one mile east of A. & M. College. Samples collected by E. N. Lowe, April 15, 1916.

AVERAGE RESULTS OF THREE ANALYSES:

	Per Cent
Moisture	1.08
Lime (CaO)	34.25
Calcium Carbonate, $CaCO_3$, (calculated)	61.12

The following table gives the analyses of other samples of limestone taken from various parts of the county. One of these samples contains 91.36 per cent of lime carbonate which is 1827.2 pounds per ton. The average amount of lime carbonate contained in the samples is 73.569 per cent or 1471.38 pounds per ton.

Table No. 30.

ANALYSES OF SELMA LIMESTONE FROM OKTIBBEHA COUNTY.

Silica (SiO_2)	29.98	25.27	9.84	20.60	17.03	18.82
Alumina (Al_2O_3)	5.45	4.81	.19	7.63	21.00	.23
Iron oxide (Fe_2O_3)	5.60	10.35	2.58	4.62	3.33	2.80
Lime (CaO)	31.62	32.85	38.65	21.81	29.29	40.02
Volatile matter (CO_2)	24.50	25.60	42.05	23.15	28.20	34.02
Magnesium oxide (MgO)	.14	.84	.18	.81	0.00	.96
Sulphur trioxide (SO_3)	.21	.62	2.05	.25	.72	2.53
Water	1.50	.40	.94	.85	.75	1.15

Table No. 30a.

Analyses of Limestone from Greensboro Road, 1-4 mile west of city limits of Starkville. Collected by E. N. Lowe, April 15, 1916.

AVERAGE RESULTS OF THREE ANALYSES:

	Per Cent
Moisture	1.35
Lime (CaO)	37.65
Calcium Carbonate, $CaCO_3$, (calculated)	67.19

Table No. 30b.

Analysis of Limestone from Greensboro Road, 300 yards west of Starkville. Collected by E. N. Lowe, April 15, 1916.

	Per Cent
Moisture	0.96
Lime (CaO)	39.07
Calcium Carbonate, $CaCO_3$, (calculated)	69.72

The limestone or chalk is easily crushed and can be applied more economically to the soils of Oktibbeha County than even imported quick lime. If a crusher cannot be obtained the larger pieces of the limestone may be broken up with a sledge. The limestone should then be applied to the soil in the fall or early winter and given the time until the planting of the crop for slaking. The disintegration may be hastened by an occasional harrowing or disking. The sandy ridges and patches of soil in the eastern part of the county and practically all of the land in the western part of the county will be greatly benefitted by an application of ground limestone. The application of quicklime is not advisable because of its destructive action on the organic matter of the soil.

PONTOTOC COUNTY.

A little less than half the area of Pontotoc County is occupied by the Ripley and the Selma divisions of the Upper Cretaceous as a bed-rock formation. Both of these formations are lime-bearing and may be used for agricultural purposes. There are also some outcrops of the Clayton limestone which belongs to the Midway division of the Eocene. Near the cotton oil mill south of the railroad station at Pontotoc a stratum of this limestone was pierced by a shallow well. The limestone contained a large number of impressions of shells. In properties it seemed very similar to the samples obtained from north of Houston. The Ripley marls and the Selma chalk are similar in appearance and composition to those in the adjacent counties. These three formations contain calcareous materials which are valuable for agricultural purposes, especially for local use but the Selma chalk contains the highest per cent of lime.

An outcrop of limestone of considerable degree of purity is located on Secs. 3 and 30, Ts. 9 and 10, R. 3 E. This limestone was burned for lime at one time. Dr. Hilgard in his Geology of Mississippi, page 103, gives the following analysis of the limestone:

Table No. 31.

ANALYSIS OF DAGGETT LIMESTONE.

Insoluble matter (chiefly sand)	8.374
Potash	0.359
Soda	0.089
Lime	48.815
Magnesia	0.751
Brown oxide of manganese	0.173
Peroxide of iron and alumina	2.412
Sulphuric acid	0.077
Carbonic acid	38.485
Water	0.832
Total	100.367

PRENTISS COUNTY.

The western half of Prentiss County is occupied by the outcrop of the Selma chalk which is the only calcareous formation of importance in the county. Although the limestone does not contain as high a per cent of lime as that in the southern part of the Selma chalk area nevertheless the percentage of lime is sufficiently high to warrant its use locally for agricultural purposes. The rock is soft and slakes rapidly and would not require a fine degree of crushing before applying to the soil.

Selma Chalk-Marl Near Booneville.—Outcrops of the Selma chalk are frequent between Booneville and the western border of the county. A bluish clayey marl is exposed in a cut on the Mobile & Ohio Railroad a few rods south of the station at Booneville. The total thickness of the bed exposed in a small draw and in the railroad cut is about forty feet. The outcrops have a surface covering of yellow loam having an approximate thickness of ten feet. The marl contains the shells of gryphea, ostrea, and other fossil genera. Where unweathered it also contains small crystals of selenite of a bright shining appearance. An analysis of a sample of the marl shows that it contains 41.52 per cent of calcium oxide and by computation 73.90 per cent of calcium carbonate though it is quite likely that a part of the calcium is in the form of calcium sulphate. Outcrops of the marl are exposed on the breaks west of Booneville and the position of the outcrops is marked by dense growths of mellilotus.

Plate V.

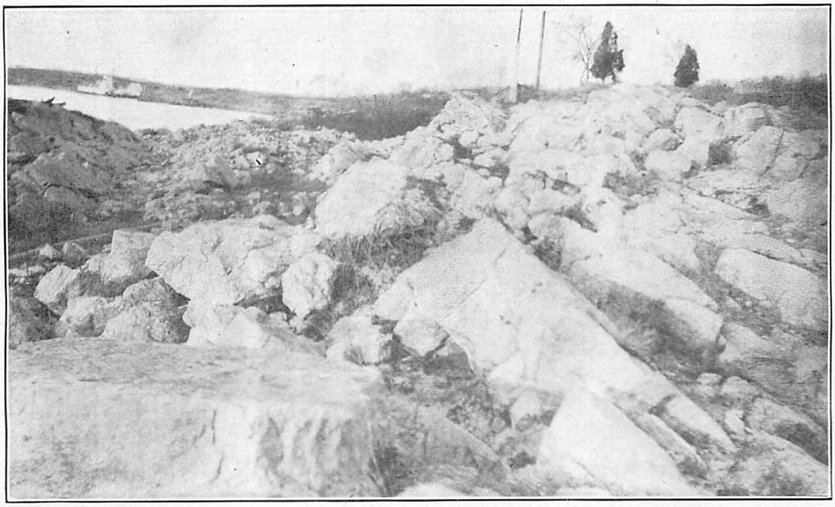


Figure 1. A Great Slide of Vicksburg Limestone on the River Front Below the Waterworks at Vicksburg. Photo by E. N. Lowe.

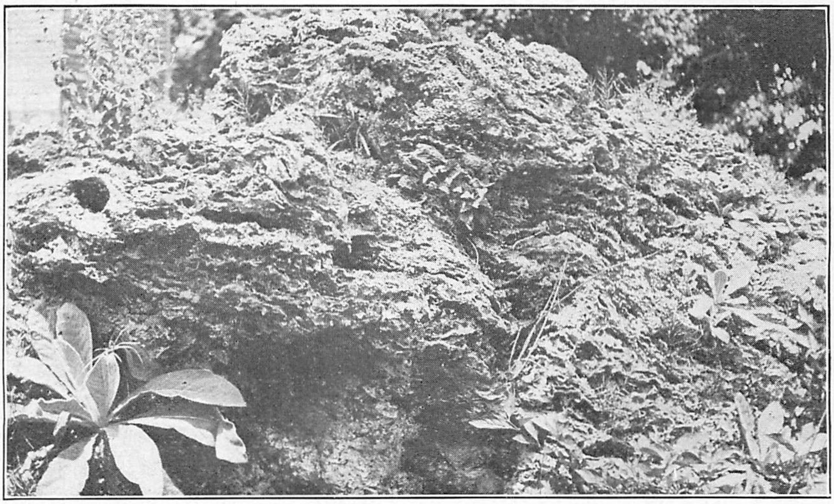


Figure 2. A Near View of a Large Mass of Highly Cellular Calcareous Tufa, Deposited at the Base of the Loess, in the Bluffs Near Milldale, Warren County. Process Now Going on, as Shown by Deposits Around Living Grass Roots. This Tufa Occurs in High Ledges Along the Valley Side. Photo by E. N. Lowe.

RANKIN COUNTY.

The outcrops of two lime-bearing formations cross Rankin County from east to west. The Vicksburg limestone and the Jackson clay marls occupy the northern part of the county and outcrop along the hillsides and in the courses of the larger streams. A covering of mantle rock conceals the outcrop at other points. The Jackson formation consists of clays and shell marls. The Vicksburg limestone occurs in layers of moderately indurated rock of varying thickness with intercalated beds of shell marl. Both the marl and the limestone may be used for agricultural purposes. The limestone should be crushed before applying but the marl may be used as it comes from the quarry.

One sample of the limestone from Brandon contains 46.04 per cent of calcium oxide (lime) and 81.95 per cent of calcium carbonate (limestone) or 1639 pounds of the latter per ton. It also contains 0.0425 per cent of phosphoric acid or 0.85 pounds per ton and 0.178525 per cent of potash or 3.67 pounds per ton. A second sample contains 48.08 per cent of calcium oxide (lime) and 85.58 per cent of calcium carbonate or 1711.6 pounds per ton of the latter. It also contains 0.12 per cent or 2.4 pounds per ton of phosphoric acid and 0.062725 per cent or 1.25 pounds per ton of potash.

The loam and sandy soils of the uplands of this county are acid and should receive lime treatment to supply calcium, to correct the acidity, to render the clay soils more porous and make them more easy to cultivate, to make the loam soils more retentive of moisture, to make the sandy soils more compact, to furnish better conditions for bacterial growth.

Brandon.—An outcrop of Vicksburg limestone occurs at the foot of the hill just east of the A. & V. station at Brandon. The same limestone is exposed in the Robinson quarry four miles east of Brandon. At this point six layers of limestone are found imbedded in marl in the following stratigraphical order:

Table No. 32.

SECTION OF VICKSBURG AT ROBINSON QUARRY, NEAR BRANDON.

13.	Soil and decomposed rock	2	feet
12.	Limestone	1 to 1½	feet
11.	Marl	1	foot
10.	Limestone	2	feet
9.	Marl	2	feet
10.	Limestone	1¼	feet
7.	Marl	1½	feet
6.	Limestone	1½ to 2	feet
5.	Marl	2	feet
4.	Limestone	2	feet
3.	Marl	1¼	feet
2.	Limestone	2	feet
1.	Marl	2	feet

The limestone has a bluish tint on fresh surfaces but weathers white on exposure. It is very fossiliferous containing abundant evidence of marine life. Large quantities of this stone have been used for rip-rap work. It has also been used locally for building purposes. The following are analyses of four samples of limestone from the Robinson quarry, W. F. Hand, analyst:

Table No. 33.

ANALYSES OF VICKSBURG LIMESTONE FROM ROBINSON QUARRY, 4 MILES SOUTHEAST OF BRANDON.

	No. 1.	No. 2.	No. 3.	No. 4.
Silica (SiO_2)	4.22	4.55	5.56	1.58
Alumina (Al_2O_3)	.75	.00	1.09	4.40
Iron oxide (Fe_2O_3)	4.37	4.25	4.01	3.31
Lime oxide (CaO)	.49.62	49.92	48.44	48.40
Magnesium oxide (MgO)	.09	.09	.78	1.27
Volatile matter (CO_2)	40.05	39.61	38.12	39.70
Sulphur trioxide (SO_3)	.36	.72	.24	.45
Moisture	.88	.95	1.61	.60

Table No. 33a.

Analyses of Limestones and Marls from Robinson Quarry, two miles southeast from Rankin, Rankin County. Collected by E. N. Lowe, August, 1915.

AVERAGE RESULTS OF THREE LIMESTONE ANALYSES:

	Per Cent
Moisture	2.30
Lime (CaO)	50.63
Calcium Carbonate, $CaCO_3$, (calculated)	90.36

Table No. 33b.

AVERAGE RESULTS OF THREE MARL ANALYSES:

	Per Cent
Moisture	3.797
Lime (CaO)	38.04
Calcium Carbonate, $CaCO_3$, (calculated)	68.36

Table No. 33c.

GENERAL AVERAGE OF LIMESTONES AND MARLS:

	Per Cent
Moisture	3.05
Lime (CaO)	44.335
Calcium Carbonate, $CaCO_3$, (calculated)	79.36

Another sample from the same locality contains 46.04 per cent of calcium oxide and 81.95 per cent of calcium carbonate. A slightly higher per cent of lime was contained in another sample which contains 48.08 per cent of calcium oxide and 85.58 per cent of calcium carbonate.

The limestone and marl from this quarry may be used to advantage in the lime treatment of lands. The marl is soft and the shells are as a rule easily disintegrated so that crushing ought not to be required and its application inexpensive. The limestone is more indurated and ought to be crushed before being applied to the soil. When crushed the maximum size of the particles ought not to exceed one or two inches in diameter, and the per cent of these to the total mass ought to be small.

This bed of limestone outcrops at intervals between Byram on Pearl River and Brandon.

Hardy Place.—On the M. F. Hardy farm 6 miles south of Jackson on the Gulf & Ship Island R. R., there occurs an outcrop of Vicksburg limestone and marl. The limestone and marl bed occurs in alternate layers of varying thickness. The following is a representation of the section exposed:

Table No. 34.

SECTION OF VICKSBURG ON HARDY PLACE.

6.	Red sandy clay (top)	5 feet
5.	Marl and limestone	4 feet
4.	Hard limestone (maximum)	1½ feet
3.	Marl	2 feet
2.	Hard irregular limestone	1 feet
1.	Marl (fossiliferous)	3 feet

The exposure is about an eighth of a mile in length. The railroad has a right of way of 200 feet in width and a large quantity of limestone taken from the cut has been placed on the right of way.

The marl contains sufficient lime carbonate to make it useful for agricultural purposes, especially for local uses. Its composing parts are very similar to those of the marl at Byram.

The limestone is also similar in appearance to that at Plain and at Byram and is probably of the same composition. There is no doubt that it contains a percentage of lime carbonate sufficiently high to render it of value for liming purposes. Limestone and marl outcrop on the Lane place west of the Hardy place.

Cassidy Plantation.—On the south fork of Homoclutto River, according to Hilgard, there is a deposit of marl which forms a prairie spot on a little hill top, about one acre in extent, and consists of a stratum some 8 feet in thickness, of a stiff dark orange-colored clay, interspersed with specks of white, limy concretions, which are largest and most abundant in the lower portion (the lowest 3 feet) of the deposit, where they occur of the size of a hen's egg and sometimes larger. The whole of the clayey mass, however, effervesces with acids. The spot bears the usual evidence of a calcareous soil in the vegetation which consists chiefly of crab-apple and a species of red haw (or hawthorn), and on its outskirts, where the soil is not excessively heavy, wild plum and honey locust also; while the other timber is thin and much stunted. The whole was probably once covered with dark colored prairie soil, which is now found only in patches; and it is stated that when the country was first settled, the spot was entirely overgrown with strawberry bushes.

The specimen analyzed represents about the average (exclusive of the large lumps of lime) of the lowest four feet. It is a hard, reddish-brown clay, with numerous white specks and veins:

Table No. 35.

ANALYSIS OF CLAY MARL, CASSADY PLANTATION.

	Per Cent.
Insoluble matter	48.475
Potash	1.242
Soda	0.152
Lime	13.190
Magnesia	1.829
Brown oxide of maganese	0.266
Peroxide of iron	5.538
Alumina	12.587
Sulphuric acid	0.033
Phosphoric acid	0.132
Carbonic acid	9.555
Water	5.876
Total	99.871

Analysis by Hilgard.

Marl is found on Town Creek, a branch of Pearl River, along by Farrish bridge, on the Mead place and on the Hinton place. Outcrops of limestone occur at intervals on the road east of Byram. A few miles out of Byram on the Deary road there is an outcrop of marl and limestone, more than 12 feet being exposed. The limestone is blue in color and fossiliferous.

Quin Place.—An outcrop of Vicksburg limestone and marl occurs 4 miles south of Brandon on the old Quin place. The marl is yellowish white in color and indurated in places into irregular layers.

The composition of the marl is given by Hilgard in the table below:

Table No. 36.

ANALYSIS OF MARL ON QUIN'S PLACE.

Insoluble matter (sand and fine silica)	13.074
Potash	0.265
Soda	0.031
Lime	46.222
Magnesia	0.614
Brown oxide of manganese	0.067
Peroxide of iron, and alumina	2.722
Phosphoric acid	trace
Sulphuric acid	0.058
Carbonic acid	34.754
Water	2.050
Total	99.857

An outcrop of marl occurs on the railroad just west of the station at Brandon. Limestone outcrops a short distance east of the station.

Plain.—There is an exposure of Vicksburg limestone and marl on the Gulf & Ship Island R. R. south of Plain. It is composed of alternate layers of limestone and marl which have the following composition:

Table No. 37.

ANALYSIS OF VICKSBURG LIMESTONE AND MARLS FROM NEAR PLAIN

Silica (SiO_2)	9.76
Alumina (Al_2O_3)	1.94
Iron oxide (Fe_2O_3)	6.46
Lime oxide (CaO)	42.56
Magnesium oxide (MgO)	.48
Volatile matter (CO_2)	35.99
Sulphur trioxide (SO_3)	.17
Moisture	1.70

SMITH COUNTY.

The greater part of the immediate surface of Smith County is covered with sandy loam soils. The sub-surface and in some places the surface in the northern part of the county is occupied by calcareous formations. The northeastern part of the county is occupied by the Jackson clay-marls as a bed rock formation. Bordering this area on the south is a narrow belt occupied by the Vicksburg limestone. Outcrops of the rock occur along the banks of the streams north of Raleigh and west of Bay Springs. The limestones and their associated marls are similar in physical characteristics to those in Rankin County and doubtless have about the same chemical compositions. If so they are suitable for liming purposes. The marls are shell marls which may be applied to the soil as they are taken from the quarry. The limestones are soft but require crushing before being applied to the soil.

Table No. 37a.

Samples of glauconitic marl of Vicksburg formation at Roger's Water Mill, 12 miles north of Taylorsville. Collected by E. N. Lowe, in June, 1913, gave the following on analysis by W. L. Perdue:

Nitrogen (NO_3)	Trace
Phosphoric Acid (P_2O_3)	Trace
Sodium and Potassium	0.82
Calcium Carbonate	28.65

Table No. 37b.

A sample from Mill Creek farther down gave the following:

Nitrogen (NO_3)	None
Phosphoric Acid (P_2O_3)	Trace
Sodium and Potassium	0.36
Calcium Carbonate	55.04

Table No. 37c.

A sample of brown limestone of Vicksburg formation from a high bluff on a creek 4 2-5 miles north of Roger's (often called Blakeney), collected by E. N. Lowe, June, 1913, analyzed by W. L. Perdue, gave the following results:

Phosphoric Acid (P_2O_3)	Trace
Potassium	.02
Calcium Carbonate ($CaCO_3$)	88.21

The Vicksburg limestone and shell marls give rise to calcareous soils of the Houston clay type. They are sometimes designated as ''shell prairie'' soils. The Jackson formation gives rise to calcareous clay soils of a very plastic nature. These soils are referred to as hog-wallow prairies. The amount of lime contained in them is not as great as in the former. They require drainage and the incorporation of organic matter.

The soils in the southern part of the county are sandy loams and silts. As a rule even the upland soils are acid and should receive an application of ground limestone.

TISHOMINGO COUNTY.

The Devonian and sub-Carboniferous formations outcrop in Tishomingo County and both contain limestones. These limestones are older and more indurated than the other limestones of the State. Consequently it will be necessary to crush them to a finer degree before applying them for agricultural purposes. The Devonian limestones range in per cent of lime (CaO) from 23.247 per cent to 39.47 per cent. The maximum amount of lime carbonate in the samples tested is about 70 per cent. One sample of limestone from Indian Creek contains 29.6 per cent of lime and 52.68 per cent of lime carbonate or 1053.6 pounds per ton of the latter. It also contains 0.1925 per cent or 3.85 pounds per ton of phosphoric acid and 0.08926 per cent or 1.78 pounds of potash per ton.

The sub-Carboniferous or Mississippian limestones lie at a higher horizon than the Devonian limestones and are separated from them by beds of chert. One sample of the sub-Carboniferous limestone from Cypress Pond contains 47.06 per cent of lime (CaO) and 84.06 per cent of lime carbonate (CaCO). This limestone is one of the best in the county for liming purposes. It should be crushed much finer than the Selma chalk in order to obtain the same results. Another sample of shaly limestone from Bear Creek near Mingo bridge contains 29.44 per cent of lime and 52.40 per cent of calcium carbonate or 1048 pounds per ton. It also contains 0.1325 per cent or 2.65 pounds per ton of phosphoric acid and 0.0265375 per cent or .53 pounds of potash per ton.

Some of the soils, especially the sandy and silt loams of the uplands of this county, are deficient in lime and would be greatly benefitted by an application of ground limestone. Alfalfa could probably be grown on some of the silt soils after an application of from two to four tons of ground limestone per acre.

A discussion of the occurrence of the Devonian and sub-Carboniferous rocks of Tishomingo County has been given in preceding pages of this report under the head, "The Geological Formations of Mississippi Containing Lime."

The following table presents the composition of some of the limestones from Tishomingo County:

Table No. 38.

ANALYSES OF LIMESTONES FROM TISHOMINGO COUNTY.

Constituent.	Per Cent				
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Insoluble matter	54.201	35.281	42.00	48.18	10.91
Alumina	1.064	1.914	1.98	3.43	8.71
Iron oxide	0.903	1.581	6.02	3.13	5.00
Lime	23.247	32.603	23.25	39.47	47.06
Magnesia	0.788	0.630	0.27	3.19	0.16
Sulphur trioxide	0.000	0.000	1.50	2.23	0.85
Carbonic acid	15.572	27.643	24.10	5.06	27.00
Organic matter and water	3.752		0.40	0.40	1.10
Potash	0.473	0.348			

Sample No. 1 is from Yellow Creek; No. 2 is from Eastport; No. 3 is from Indian Creek; No. 4 is from Eastport; No. 5 is from Cypress Pond.

TIPPAH COUNTY.

There are three calcareous formations in Tippah County. The Selma chalk occupies the southeastern part of the county and the Ripley marls the central portion. The impure limestones of the Midway border the Ripley marls on the west. The Selma chalk probably contains about the same amount of lime carbonate as that in adjoining counties. The Midway limestone is similar in appearance and doubtless in composition to that in Chickasaw County.

Ripley Marls.—One of the best exposures of Ripley marl is to be found at Owl Creek Bluff on the Hill farm east of Ripley. The outcrop contains a sandy shell marl and layers of shell rock of great irregularity. The marl is of the glauconitic or green sand type. The following is the analysis of a specimen of the marl from Tippah County made by L. Harper:

Table No. 39.

ANALYSIS OF TIPPAH COUNTY MARL.

Constituent.	Per Cent.
Silicic acid	0.400
Sulphuric acid	2.370
Carbonic acid	4.577
Phosphoric acid	0.652
Lime	9.474
Magnesia	1.677
Oxides of iron and manganese	3.707
Alumina	3.121
Potash	1.533
Organic matter and water	4.550
Insoluble remnant of silica and alumina	67.939
Total	100.00

This marl according to the above analysis contains 630.6 lbs. of lime carbonate, 13.4 pounds of phosphoric acid and 30.66 pounds of potash per ton. These constituents render it valuable as a fertilizer for local use.

A sample of marl taken from Sec. 27, T. 2, R. 4 E. was analyzed by Dr. Hilgard with the following results:

Table No. 40.

ANALYSIS OF WILHITE MARL.

		Ripley Marl.
	1.	2.
Insoluble sand and clay	73.410	62.441
Potash	0.702	0.730
Soda	(and lost)	0.272
Lime	6.315	7.952
Magnesia	0.886	1.560
Brown oxide of manganese	0.050	0.160
Peroxide of iron	7.055	11.849
Alumina	5.888	5.865
Phosphoric acid	0.046	0.266
Carbonic acid, water and loss	5.640	9.905
Total	100.000	100.000

This marl contains only 287 pounds of calcium carbonate, 92 pounds of phosphoric acid and 14.04 pounds of potash per ton. On account of its very low lime content its use should be restricted to local purposes.

The second analysis is of a sample collected by Dr. Hilgard from the O. Davis well in Ripley. It contains 360.4 pounds of calcium carbonate, 14.6 pounds of potash and 5.32 pounds of phosphoric acid per ton. It contains slightly more potash and lime and nearly five times as much phosphoric acid as the Wilhite marl.

UNION COUNTY.

There are lime-bearing rocks in Union County. The bed-rock formations in the eastern part of the county are calcareous in composition. These formations belong to the Selma and the Ripley divisions of the Upper Cretaceous and to the Clayton division of the Eocene.

The Clayton limestone forms a very narrow belt just east of the Flatwoods in the central part of the county. The Ripley marls outcrop in a belt about eight miles in width a little east of the central part of the county. The Selma chalk forms the bed-rock for the remainder of the eastern part of the county. These bed-rock formations have their surfaces more or less concealed by mantle rocks. The properties of these lime-bearing formations are similar to those of the formations in the adjoining counties and the reader is referred to the discussion there given.

The western part of Union County has its surface occupied with soils to which an application of lime would be beneficial. The soils derived from the Flatwoods clay are silty clay soils which are deficient in lime. An application of lime would improve the texture of these soils and also their fertility. Some of the transported soils of the Flatwoods which are derived from the lime-bearing lands to the east are not deficient in lime but the residual soils and those in which the material has been transported from the west are deficient. The soils derived from the Wilcox formation lying west of the Flatwoods are also deficient in lime. The lime-bearing materials of the county can therefore be used on the soils within the county to profitable advantage.

Plate VI.

Falls Over a Ledge of Vicksburg Limestone Near Milldale, Warren County.
Photo by E. N. Lowe.

WARREN COUNTY.

The principal lime-bearing formation of Warren County is the Vicksburg limestone. There are some lime concretions in the loess but they are not sufficiently numerous or concentrated to be of much value for liming purposes. The calcareous clays of the Jackson underlie the limestones and are visible in some outcrops.

The Vicksburg formation consists of a series of beds of limestone of varying thickness intercalated with beds of shell marl. The chief outcrops are found along the banks of the Yazoo and the Mississippi rivers. The limestone is not very highly indurated and could be crushed without a great deal of expense. The shell marl is composed of sand, clay and shells. It contains from 35 to 40 per cent of lime. It can be applied to the soil without crushing. One sample limestone contains 90.41 per cent of calcium carbonate or 1808.2 pounds per ton. An average of eight samples of limestones and marls contains 77.12 per cent of calcium carbonate or 1542.4 pounds per ton. One sample of the marl contains 0.135 per cent or 2.70 pounds per ton of phosphoric acid and 0.758 per cent or 15.16 pounds per ton of potash.

The greater part of the surface of Warren County is covered with soils derived from the loess. These soils as a rule are not very deficient in phosphoric acid or in potash. In many areas the soils have become deficient in lime and applications of ground limestone should be made, especially before any attempt is made to grow alfalfa.

Vicksburg Limestone.—In the northern part of Vicksburg along the river road to the National Cemtery there is an exposure of limestone and marl having a total thickness of more than 20 feet. The individual layers of limestone vary from 1 to 5 feet and the marl layers have about the same thickness. The outcrop extends parallel with the road in a vertical face for more than a quarter of a mile. The southern part has very little over-burden.

Hilgard gives the following as the composition of a sample of this limestone:

Carbonate of lime	87.808%
Sharp sand	0.207
Other impurities	11.985
Total	100.000%

Vicksburg.—The following is an analysis by Hilgard of a sample of the Vicksburg marl:

Table No. 41.

VICKSBURG MARL.

Coarse sand	3.700
Clay and fine sand	17.267
Potash	0.758
Soda	0.283
Lime	37.543
Magnesia	2.083
Peroxide of iron, and alumina	4.722
Phosphoric acid	0.135
Carbonic acid (and loss)	30.838
Water	2.657
Total	100.00%

Vicksburg Limestone and Marls.—The Vicksburg limestone in Warren County is a fine grained stone from 1 to 5 feet in thickness and intercalated with calcareous marls containing a large number of marine shells. The typical exposure of the beds is along the bluffs at Vicksburg. The following section is from near the oil mill on the river bluff:

Table No. 42.

9.	Loess in the bluff back from the river	100 feet
8.	Marl	2 feet
7.	Ledge of hard limestone	3 feet
6.	Bed of soft marl	3 feet
5.	Ledge of limestone	5 feet
4.	Marl stratum	5 feet
3.	Ledge of hard limestone	5 feet
2.	Hard limestone	3 feet
1.	Bed of compact marl	5 feet

The thickness of the exposure in the above section is about one-third of the entire thickness of the Vicksburg formation.

Analysis of each stratum from Nos. 1 to 7, inclusive, was made with the following results. The numbers of the analyses correspond to the numbers in the above section:

Table No. 43.

ANALYSES OF VICKSBURG LIMESTONES AND MARLS FROM VICKSBURG.

Constituent.	Per Cent			
	No. 1.	No. 2.	No. 3.	No. 4.
Silica (SiO_2)	32.45	6.43	7.39	25.27
Alumina (Al_2O_3)	2.12	0.31	1.02	4.50
Iron oxide (Fe_2O_3)	2.05	2.00	2.48	5.37
Lime (CaO)	34.20	50.25	47.50	29.40
Volatile matter (CO)	26.65	39.00	38.65	24.10
Magnesium oxide (MgO)	.38	1.36	1.45	1.99
Sulphur trioxide (SO_3)	.08	.36	.51	2.76
Moisture (H_2O)	1.60	.61	1.10	3.95
Total	99.53	100.32	100.10	97.34

Table No. 44.

ANALYSES OF VICKSBURG LIMESTONES AND MARLS FROM VICKSBURG.

Constituent.	Per Cent			
	No. 5.	No. 6.	No. 7.	No. 8.
Silica (SiO_2)	5.58	13.62	3.10	7.08
Alumina (Al_2O_3)	1.00	3.00	.25	.61
Iron oxide (Fe_2O_3)	2.18	2.75	1.62	2.50
Lime (CaO)	49.97	40.37	50.63	50.44
Volatile matter (CO_2)	36.26	33.66	41.00	37.22
Magnesium oxide (MgO)	1.01	1.72	.99	1.07
Sulphur trioxide (SO_3)	.30	.98	.60	.38
Moisture (H_2O)	.82	2.75	.60	.40
Total	100.12	98.85	98.79	97.70

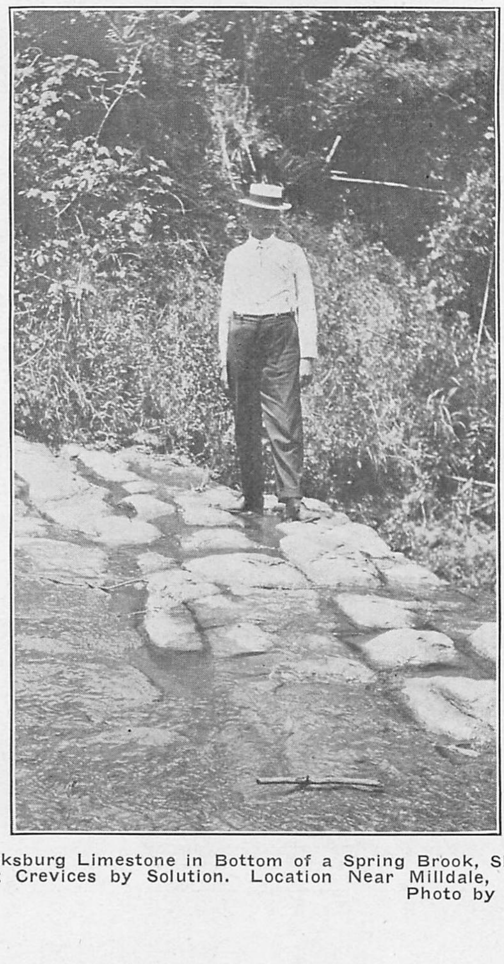
Table No. 45.

AN AVERAGE OF Nos. 1, 2, 3, 4, 5, 6, 7, 8.

Constituent.	Per Cent.
Silica (SiO_2)	13.41
Alumina (Al_2O_3)	1.74
Iron oxide (Fe_2O_3)	2.63
Lime (CaO)	43.20
Volatile matter (CO_2)	34.62
Magnesium oxide (MgO)	1.39
Sulphur trioxide (SO_3)	.79
Moisture (H_2O)	1.63
Total	99.31

No. 8 is a limestone from Steel's Bayou, Vicksburg. (See Bulletin No. 1, of the Survey Reports).

Plate VII.



Exposure of Vicksburg Limestone in Bottom of a Spring Brook, Showing Enlargement of Joint Crevices by Solution. Location Near Milldale, Warren County.
Photo by E. N. Lowe.

WAYNE COUNTY

There are two calcareous formations outcropping in Wayne County. The Jackson marls and clays occupy the sub-surface and a part of the surface in the northern part of the county. The Vicksburg limestone runs in a narrow belt diagonally across the county near the north-central part. The limestone varies in the amount of lime which it contains. One sample collected near Waynesboro contains 14.48 per cent of calcium oxide (lime) and 25.77 per cent of calcium carbonate or 515.4 pounds per ton of the latter. It contains 0.135 per cent of phosphoric acid or 2.7 pounds per ton and 0.05996 per cent of potash or 1.19 pounds per ton. This sample was a sample of the weathered rock and does not run as high in fertilizing constituents as some of the other samples collected from outcrops in the county. The three samples from Red Hill contain an average of 46.71 per cent of calcium oxide and 83.94 per cent or 1678.8 pounds per ton of calcium carbonate. One sample of the Jackson marl contains 7.38 pounds and the other 12.42 pounds of potash per pound. The one contains 2.42 pounds and the other 3.6 pounds of phosphoric acid per ton.

There are large areas of sandy and loamy soils in Wayne County on which these lime-bearing materials may be used with profit. The fertility of these soils may be increased by adding from 2 to 4 tons of ground limestone per acre, planting to a leguminous crop and plowing it under when it becomes grown. This method will increase the availability of the potash and the phosphoric acid in the soil but in some instances the total amount of phosphoric acid is so small that ground phosphate rock should be added with the green manure. The average amount of phosphorus in some of the soils is only 540 pounds per acre while it ought to be at least as much as 1,000 pounds.

Waynesboro.—The Vicksburg limestone is exposed at several points about Waynesboro. About 1¼ miles north on the Boyce road there is an outcrop of limestone in a small creek both in the bed and on the valley wall. The total exposure is ten or twelve feet. The top layers are soft and very fossiliferous. The lowermost layer is harder and forms a resistant layer. There are several other outcrops on the Boyce road to the north of this point. One mile south of Boyce on the top of a hill there is an exposure of marl and limestone. The marl layer, which is at the top, has a thickness of about 12 feet and is highly fossiliferous. It is so soft as to be easily handled with pick and shovel. The limestone layer at the bottom has a thickness of about 18 inches. There are several acres in this exposure in which the over-burden is only a few feet.

Boyce.—Along the railroad between Boyce and Waynesboro there are several outcrops of the Vicksburg limestones and marls. Just beyond Woodword Switch, 1½ miles north of Waynesboro, such occurs in a small cut east of the M. & O. R. R. Several layers of limestone 3 to 4 feet in thickness are separated by layers of marl. Another exposure of 12 feet or more occurs in a small creek one-half mile north of the switch. Another exposure was found in a small draw near the railroad where a layer of firm rock occurs in a small depression. The over-burden at this point is about 8 feet. Two miles south of Boyce the M. & O. R. R. cuts through a ledge of limestone. Several layers are exposed with only a small over-burden.

Jackson Marls.—The calcareous marls of the Jackson formation form a considerable part of the sub-surface of Wayne County and are exposed along many of the stream courses. Their value for local agricultural uses cannot be questioned. Chemical analyses show that they contain lime, potash and phosphate. See the following table for the analyses of two samples, one from the Chickasawhay River at Davis Ferry and the other from Limestone Creek:

Table No. 46.

ANALYSES OF JACKSON MARLS, FROM WAYNE COUNTY.

	No. 1.	No. 2.
Insoluble matter	55.185	56.787
Alumina	1.956	.855
Lime	19.508	20.793
Potash	.621	.369
Soda	.129	.178
Magnesia	.950	.833
Brown oxide manganese	.192	.032
Peroxide of iron	1.194	1.928
Phosphoric acid	.180	.121
Sulphuric acid	1.804	.085
Carbonic acid	17.662	16.273
Organic matter and water	00.000	1.100
Total	99.666	99.351

Analyses by Hilgard.

Vicksburg Marl.—The Vicksburg formation in Wayne County contains both marls and limestones. The marls may be used to advantage in the liming of soils. As a rule they contain more lime than the Jackson marls and about the same per cent of potash and phosphate. The following analysis is of a sample of Vicksburg marl from Long's Mill:

Table No. 47.

ANALYSIS OF VICKSBURG MARL, WAYNE COUNTY.

Insoluble matter	23.282
Alumina	2.726
Lime	37.633
Potash	.295
Soda	.255
Magnesia	1.188
Brown oxide of manganese	.088
Peroxide of iron	2.200
Phosphoric acid	.119
Sulphuric acid	.312
Carbonic acid	29.500
Organic matter and water	2.524
Total	100.122

Table No. 47a.

Analyses of Limestone from Bluff of Little Limestone Creek, three miles north of Waynesboro. Collected by E. N. Lowe, April, 1916.

AVERAGE RESULTS OF FOUR ANALYSES:

	Per Cent
Moisture	0.75
Lime (CaO)	51.75
Calcium Carbonate, $CaCO_3$, (calculated)	92.345

Table No. 47b.

Analysis of Limestone from bottom of Big Limestone Creek, three miles north of Waynesboro. Collected by E. N. Lowe, April, 1916.

RESULTS OF ANALYSIS:

	Per Cent
Moisture	0.66
Lime (CaO)	52.375
Calcium Carbonate, $CaCO_3$, (calculated)	93.375

Table No. 47c.

Analyses of Limestone from Cut on M. & O. R. R., between Little and Big Limestone Creeks. Collected by E. N. Lowe, April, 1916.

AVERAGE RESULTS OF TWO ANALYSES:

	Per Cent
Moisture	0.14
Lime (CaO)	55.36
Calcium Carbonate, $CaCO_3$, (calculated)	98.79

Vicksburg Limestone.—A layer of Vicksburg limestone occurs in the bed of the Chickasawhay River above the wagon bridge at Waynesboro and along the banks of the river up to the mouth of Yellow Creek, a western tributary of the Chickasawhay River. There are also exposures of limestone along the banks of Yellow Creek for a distance of three or four miles up the creek, the channel of the stream having been carved in the limestone.

On the Plummer place, up Yellow Creek, about three miles northwest from Waynesboro, a quarry has been opened in the limestone. The rock is soft and easily cut with a saw. In quarrying, the rock is sawed out in blocks. These blocks while soft in the quarry after losing some quarry water, become slightly indurated. The stone has been used only locally in the building of chimneys and for foundations. The ease with which it may be crushed renders it especially adapted for agricultural purposes. The following is the analyses of three samples of Vicksburg limestone from Red Hill, Wayne County:

Table No. 48.

ANALYSES OF VICKSBURG LIMESTONE FROM RED HILL, WAYNE COUNTY.

	No. 1.	No. 2.	No. 3.
Silica (SiO_2)	6.30	15.05	9.20
Alumina (Al_2O_3)	7.20	5.35	6.65
Iron oxide (Fe_2O_3)	7.20	5.35	6.65
Lime (CaO)	48.44	44.58	47.12
Carbon dioxide (CO_2)	38.06	35.02	37.03
Water	n.d.	n.d.	n.d.

These samples of limestone contain an average of 83.94 per cent or 1678.8 pounds per ton of calcium carbonate. The first sample contains 86.5 per cent or 1730 pounds per ton of lime carbonate (calcium carbonate). This limestone is well suited for local use in the liming of lands. The rock is soft and it would not be necessary to crush it finer than a degree in which the larger particles would have a diameter of from one to two inches.