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DEPARTMENT OF REGISTRATION AND EDUCATION
FRANK G. THOMPSON, *Director*

DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*
URBANA

CIRCULAR NO. 94

AGRICULTURAL LIMESTONE RESOURCES OF ILLINOIS

THEIR CHARACTER AND OCCURRENCE AND METHODS OF EXAMINATION

By

J. E. LAMAR

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
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CONTENTS

ILLUSTRATIONS

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Introduction

The agricultural limestone resources of Illinois have become increasingly important as the value of agstone as a soil amendment has become more and more widely known and as the tonnages of such stone applied to the soils of Illinois have grown. At present the wartime necessity of producing larger crops and at the same time maintaining soil fertility makes agstone and the State's agricultural limestone resources of even greater than ordinary importance. A wide variety of questions relating to these resources have been raised by farm advisers, farmers, quarrymen, and others vitally interested in keeping up the flow of agstone to the farms of Illinois and in utilizing to the best advantage the limestone resources of the State. It is believed that the information given herein will answer the more important of these questions and will provide an understanding of the basic geological factors governing the character, occurrence, and development of the agricultural limestone resources of Illinois.

Formation of Limestone

Limestone may be defined roughly as a sedimentary rock containing more than 50 per cent of calcium carbonate or more than 50 per cent of the carbonates of calcium and magnesium together. Most limestones were formed as sediments in seas or oceans which were doubtless salty and in other ways similar to modern oceans. Some limestones were deposited as lime-muds; others were largely an accumulation of shells and the hard parts of numerous marine animals which were mostly of relatively small size. Such animal remains when petrified are called fossils and are often popularly known as petrified clams, "Indian beads," "fish backbones," petrified "hickory nuts," and petrified "butterflies" (fig. 1).

While the lime-muds and organic remains were accumulating on the bottoms of the ancient seas, varying amounts of clay, silt, and sand were being carried into these oceans by rivers and streams. Thus most limestones contain some impurities, that is, materials such as clay, silt, or sand, that are not carbonates. Some limestones characteristically contain very little of such noncarbonate materials, others are commonly impure.

Chert, also sometimes called flint, is another impurity found in limestone. It occurs as beds, rounded nodules, or irregular masses. It has probably been formed in several different ways which are not well understood in detail. Some chert may have accumulated on the sea-bottom as a silica gel which was subsequently compacted to the layers and nodules now evident in many limestone formations. Other chert deposits are believed to have been formed in the rock by the action of groundwater.

Limestone deposition in the ancient seas was usually terminated by changes which resulted in an influx of great quantities of sand or mud. These and other sediments buried the accumulations of lime-muds, shells, and the like, causing them to become compacted and hardened into solid limestone rock. In the course of ages, rivers and streams have worn away the overlying rocks and exposed the linestone over wide areas in some regions, only locally in others.

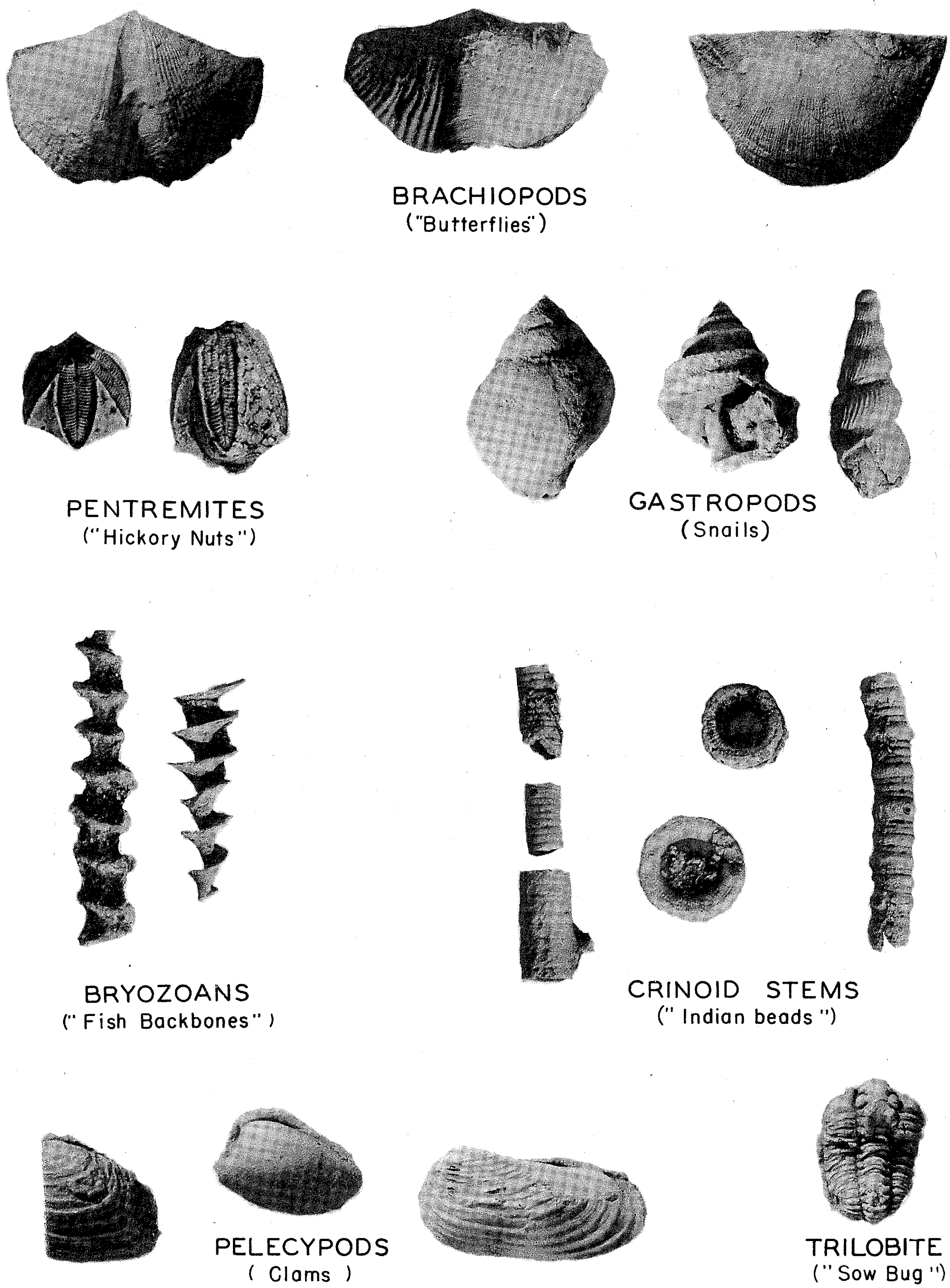


Fig. 1. - Fossils found in Illinois limestones. The scientific names of the fossils are given together with their common or popular names.

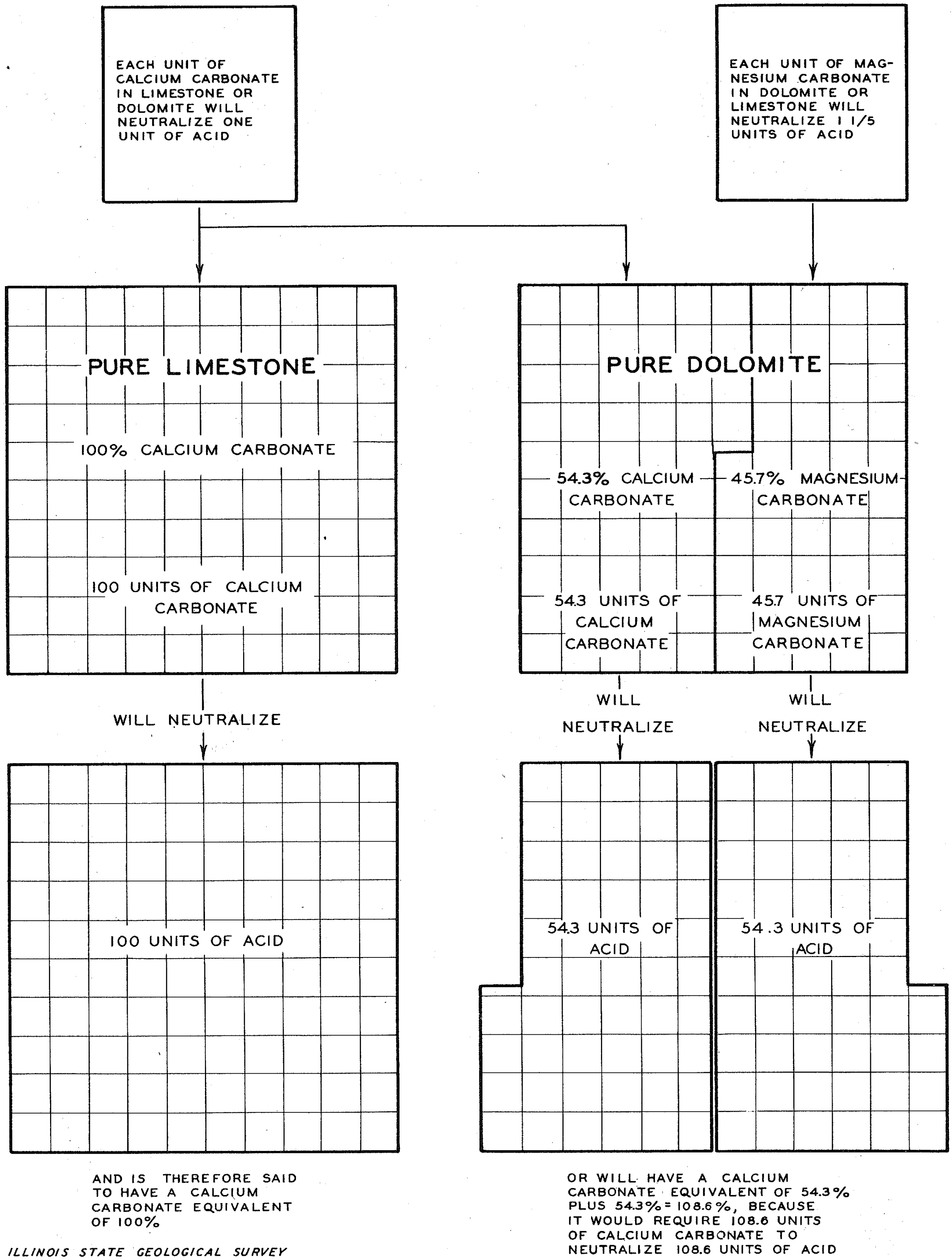


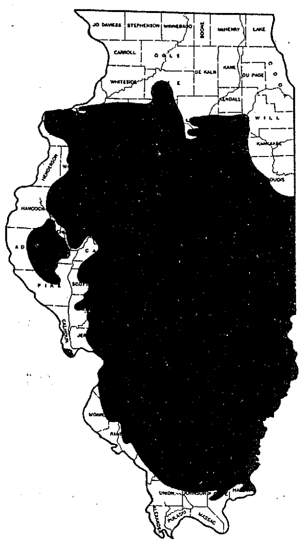
Fig. 2. - Calcium carbonate equivalents of limestone and dolomite.

Kinds of Limestone and Their Neutralizing Value

There are in Illinois a great many varieties of limestone. They range from very fine-grained to coarse-grained. Some are composed largely of fragments of fossil shells or other animal remains, others of small rounded grains known as oolite grains, and still others of fine particles of certain carbonate minerals. All varieties, if sufficiently pure, serve well as agstone.

Most Illinois limestones may be classified into two major groups on the basis of chemical composition - calcitic limestones and dolomitic limestones. The first of these, the calcitic limestones, are composed principally of the mineral calcite and consist largely of calcium carbonate with only minor amounts of magnesium carbonate. Such rocks will hereafter in this paper be referred to merely as limestones. Dolomitic limestones, on the other hand, are composed mainly of the mineral dolomite whose chemical composition is 54.3 per cent calcium carbonate and 45.7 per cent magnesium carbonate. Rocks of this kind will subsequently be referred to as dolomites. Both types of stone are efficient neutralizers of acid and are therefore satisfactory agstones.

The neutralizing value of agstone is expressed in terms of calcium carbonate equivalent, often abbreviated C.C.E. A perfectly pure limestone would be composed entirely of calcium carbonate and would, therefore, have a calcium carbonate equivalent of 100 per cent. Pure dolomite, however, has a neutralizing value, or C.C.E., of 108.6 per cent because the magnesium carbonate in the dolomite is a better neutralizer of acids than calcium carbonate to the extent that a pound of magnesium carbonate will neutralize almost 1/5 more acid by weight than will a pound of calcium carbonate (fig. 2). Therefore, if the neutralizing value of a pound of calcium carbonate is 100 per cent, the neutralizing value of a pound of magnesium carbonate would be about 1/5 more or 120 per cent calcium carbonate equivalent. The exact figure is 118.7 per cent.



PENNSYLVANIAN SYSTEM
"COAL MEASURES"
THICKNESS - 2500 FEET

OMEGA LIMESTONE
LA SALLE "
LIVINGSTON "
SHOAL CREEK "
PONTIAC "
LONSDALE "
CUTLER "
BRERETON "
ST. DAVID "

MISSISSIPPIAN SYSTEM
THICKNESS - 3400 FEET

KINKAID LIMESTONE
MENARD "
GLEN DEAN "
GOLCONDA "
STE. GENEVIEVE "
ST. LOUIS "
SALEM "
WARSAW "
KEOKUK "
BURLINGTON "
CHOUTEAU "

DEVONIAN SYSTEM

N. ILLINOIS	S. ILLINOIS
THICKNESS - 150 FT.	THICKNESS - 1450 FT.
CEDAR VALLEY LS.	GRAND TOWER LS.
WAPSIPINICON "	BACKBONE "
	BAILEY "

SILURIAN SYSTEM

N. ILLINOIS	S. ILLINOIS
THICKNESS - 400 FT.	THICKNESS - 400 FT.
NIAGARAN DOLOMITE	NIAGARAN DOLOMITE
KANKAKEE "	SEXTON CK. LS.
EDGEWOOD "	EDGEWOOD DOLOMITE
	GIRARDEAU LS.

ORDOVICIAN SYSTEM

N. ILLINOIS	S. ILLINOIS
THICKNESS - 1500 FT.	THICKNESS - 750 FT.
GALENA DOLOMITE	KIMMSWICK LS.
PLATTEVILLE "	PLATTIN "
SHAKOPEE "	

ILLINOIS STATE GEOLOGICAL SURVEY

Fig. 3. - Maps showing the distribution of the consolidated bedrock formations of Illinois according to major rock groups or geologic systems. The central column shows the succession of the various systems from the oldest at the bottom of the column to the youngest at the top. Under each system is given the approximate maximum thickness of the exposed strata comprising it and the names of the important limestone or dolomite formations in their approximate order of age. Because some of the limestone and dolomite formations in the Ordovician, Silurian, and Devonian systems occur only in northern or in southern Illinois, the central column is divided to show these differences. Most of the formations named in the column are being or have been used as sources of agstone. Formations composed principally of sandstone, shale, or chert are not indicated but one or more such formations are present in all systems, though they are minor in the Silurian system.

Distribution of Limestone and Dolomite Resources of Illinois

As mentioned, the limestone and dolomite formations were laid down as sediments in oceans. One characteristic of such deposits is that they are flat-lying. Any extensive tilting which these limestone and dolomite beds now exhibit is therefore the result of movement of the earth's crust, chiefly upwarping or downfolding. If the rocks of Illinois were perfectly flat-lying and the surface of the ground likewise was flat, only one rock formation would be exposed. But the rock formations are not flat-lying and the ground surface is not level. Actually the bedrock in most of the State is downwarped so that any single extensive bed has a similarity to the bowl of a huge spoon, with the tip of the spoon in northern Illinois, the deepest part of the bowl in southeastern Illinois, and one edge extending into Indiana.

The distribution of the bedrock limestone formations is approximately as shown in figure 3. When the various maps of figure 3 are combined and interpreted in relation to the distribution of the limestone and dolomite resources of the bedrock formations, the results are those shown in figure 4. The great central part of the State is underlain by coal-bearing formations, commonly referred to as the "Coal Measures," most of which are shale and sandstone but a number of limestones, usually thin, are present. The "Coal Measures" are the youngest consolidated bedrock of the State. Next oldest are the great group of beds known as the Mississippian rocks, which include many thick limestone formations and crop out in western, southwestern, and southern Illinois. Below these lie the Devonian rocks which are exposed in western and southern Illinois. They in turn are succeeded throughout much of the State by the Silurian rocks, which are dolomite formations of great thickness, exposed chiefly in northern Illinois. The oldest rocks exposed at all extensively in the State are the Ordovician rocks, which are comprised of both limestone and dolomite formations and also crop out in northern and southwestern Illinois.

This geological picture is, however, not quite complete. Over the bedrock of

Illinois ancient glaciers spread huge deposits of pebbly clay, with some silt, sand, and gravel. Dust storms ensued and spread a mantle of clayey silt, known as loess, over large parts of the State, especially those areas near major rivers. The thickness of these glacial and wind deposits varies, but over much of the State they effectively conceal most of the bedrock. Consequently the availability of the limestone or dolomite resources of any given area depends not only on the kind of rock formations lying below the surface but also on the thickness of the glacial deposits and on the amount of subsequent valley erosion.

Figure 5 combines the data in figure 4 with information regarding thickness of glacial deposits and other data and shows the available limestone resources of Illinois. The areas mapped in northern, western, and southern Illinois are those wherein limestone or dolomite crops out at many places. In the central part of the State underlain by "Coal Measures" formations, the mapped areas indicate those tracts where limestone more than 3 feet thick crops out at some places. For the most part these limestones are less than 10 feet thick, often less than 5 feet thick, although locally, as in the vicinity of LaSalle, Danville, Charleston, Pontiac, Peoria, Lincoln, Marshall, DuQuoin, Athens, Butler, and other places, beds thicker than 10 feet but rarely exceeding 25 feet are present. The chances for thick limestone deposits are therefore less favorable in those counties underlain by "Coal Measures" rocks than in most other parts of the State.

Limestone and Dolomite Formations Used for Agstone

Some of the several limestone beds in the Pennsylvanian system or "Coal Measures" (fig. 3) are comparatively pure and are quarried at many places for making agstone; other beds are too impure to be suitable. However, even some of the purer beds are likely to vary in composition from layer to layer and also from one part of the deposit to another. Their composition is most likely to be consistent where the

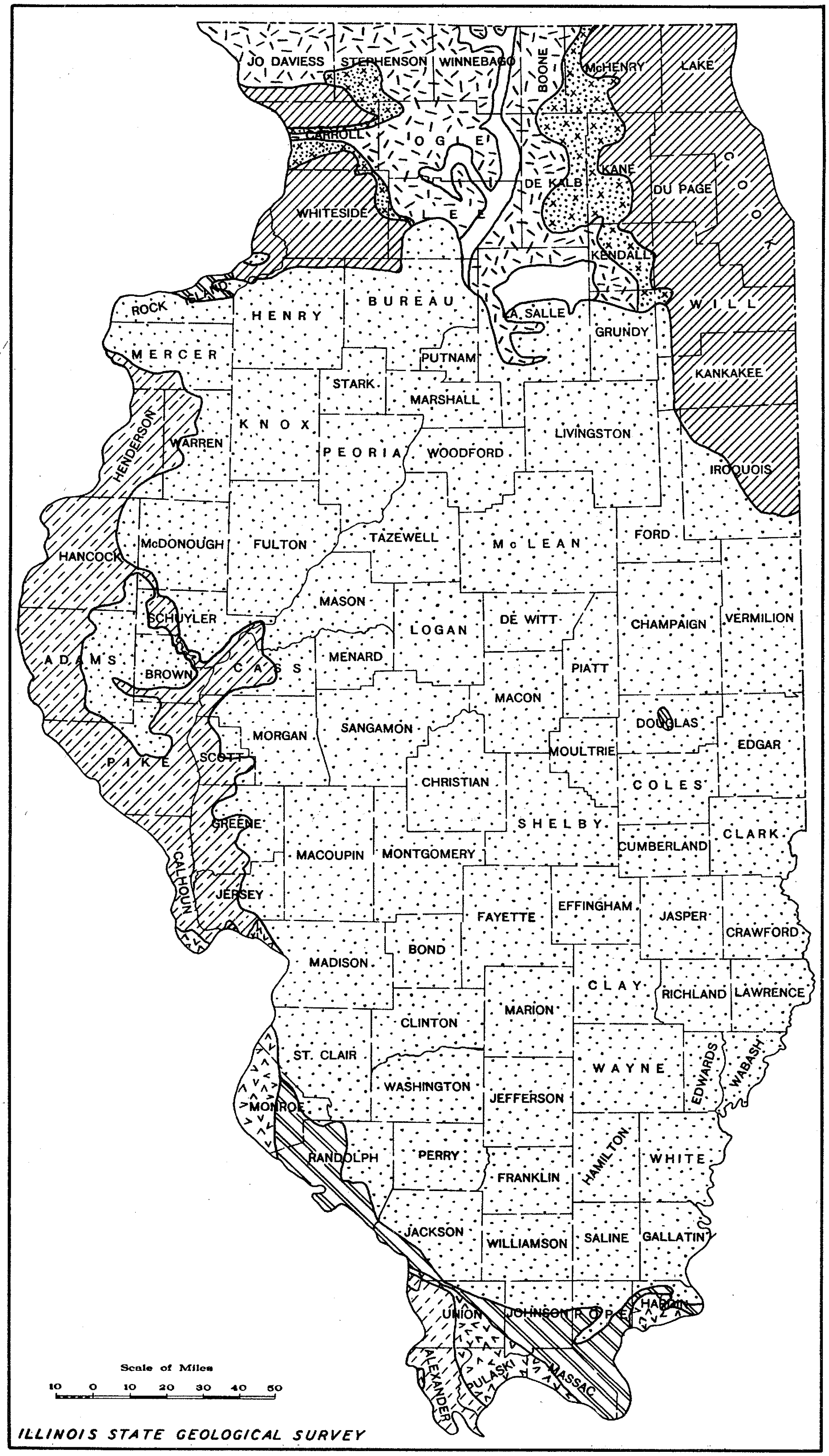

JO DAVIESS
STEPHENSON
WINNEBAGO
BOONE
McHENRY
LAKE
CARROLL
OGLE
DE KALB
KANE
DU PAGE
COOK
WHITESIDE
LEE
KENDALL
ROCK ISLAND
HENRY
BUREAU
LA SALLE
WILL
GRUNDY
MERCER
PUTNAM
STARK
MARSHALL
KANKAKEE
HENDERSON
WARREN
KNOX
PEORIA
WOODFORD
LIVINGSTON
IROQUOIS
HANCOCK
McDONOUGH
FULTON
TAZEWELL
McLEAN
FORD
SCHUYLER
MASON
LOGAN
DE WITT
CHAMPAIGN
VERMILION
ADAMS
BROWN
CASS
MENARD
PIATT
MACON
MORGAN
SANGAMON
DOUGLAS
PIKE
SCOTT
MOULTRIE
EDGAR
CHRISTIAN
COLES
GREENE
SHELBY
CLARK
MACOUPIN
MONTGOMERY
CUMBERLAND
CALHOUN
JERSEY
EFFINGHAM
JASPER
FAYETTE
CRAWFORD
BOND
MADISON
CLAY
RICHLAND
LAWRENCE
MARION
CLINTON
ST. CLAIR
WAYNE
EDWARDS
WABASH
WASHINGTON
JEFFERSON
MONROE
HAMILTON
RANDOLPH
PERRY
WHITE
FRANKLIN
JACKSON
WILLIAMSON
SALINE
GALLATIN
UNION
JOHNSON
POPE
HARDIN
ALEXANDER
PULASKI
MASSAC
Scale of Miles
10 0 10 20 30 40 50
ILLINOIS STATE GEOLOGICAL SURVEY

Fig. 4. - Generalized map showing the distribution and nature of the limestone and dolomite formations of Illinois.

Legend

Thick dolomite formations.

Thick dolomite formations; in some places includes limestone formations mostly less than 30 feet thick.

Thick limestone formations.

Thick limestone formations; much of the limestone is cherty; in places includes dolomite formations mostly less than 30 feet thick.

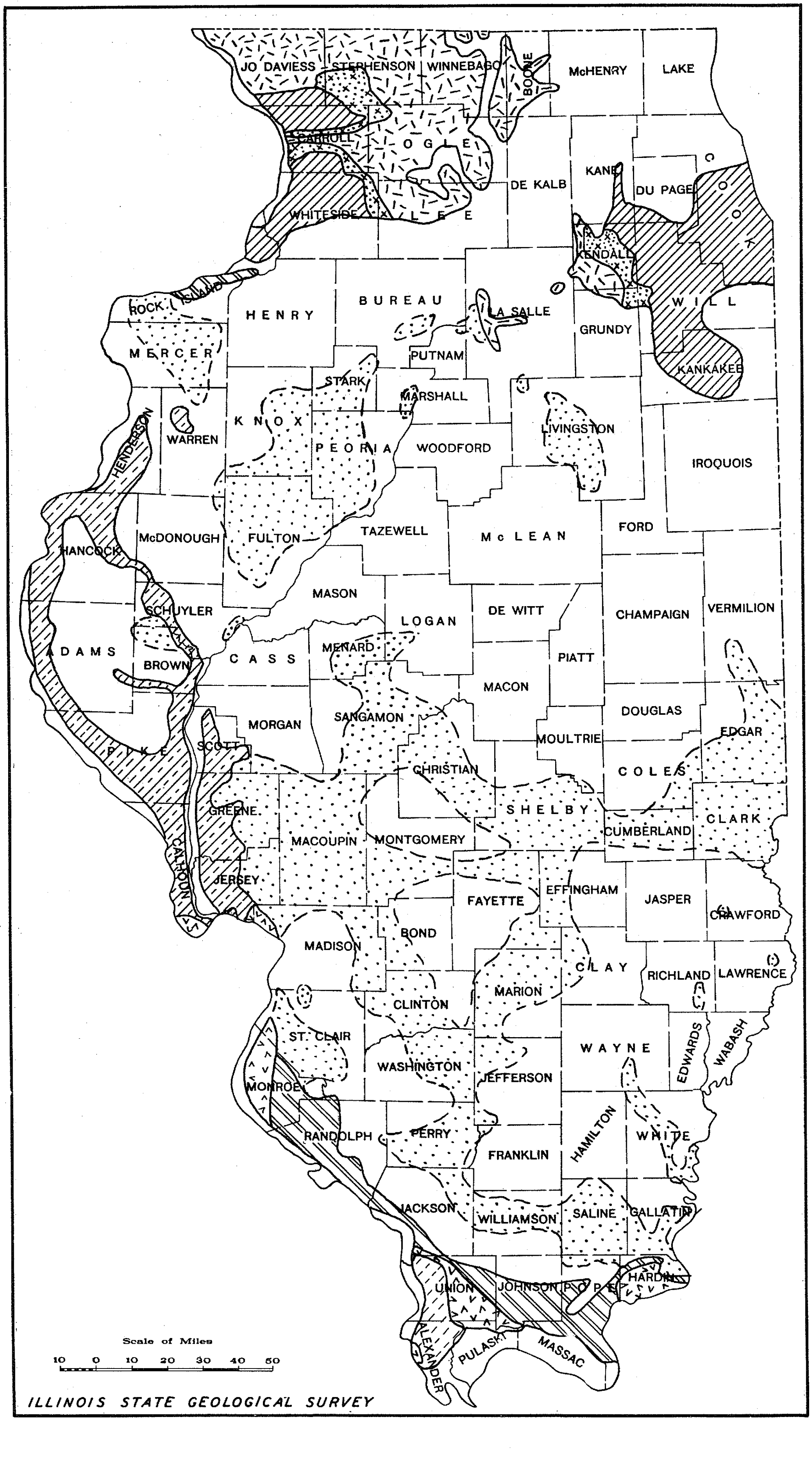
Limestone formations ranging from thick to thin, interbedded with thick to thin sandstone and shale formations.

Mostly shale but in some places includes limestone formations usually less than 30 feet thick.

Mostly chert formations or limestone formations containing large amounts of chert and other siliceous materials.

Area underlain by "Coal Measures" formations, comprised mainly of shale and sandstone but with limestone formations, generally less than 10 feet thick, present in some places.

Limestone and dolomite formations absent.


JO DAVIESS
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ROCK ISLAND
HENRY
BUREAU
LA SALLE
GRUNDY
WILL
MERCER
PUTNAM
KANKAKEE
STARK
MARSHALL
WARREN
KNOX
PEORIA
WOODFORD
LIVINGSTON
HENDERSON
IROQUOIS
McDONOUGH
FULTON
TAZEWELL
McLEAN
FORD
HANCOCK
MASON
SCHUYLER
LOGAN
DE WITT
CHAMPAIGN
VERMILION
ADAMS
BROWN
CASS
MENARD
PIATT
MACON
MORGAN
SANGAMON
DOUGLAS
PIKE
SCOTT
MOULTRIE
EDGAR
CHRISTIAN
COLES
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FAYETTE
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RICHLAND
LAWRENCE
MARION
CLINTON
ST. CLAIR
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WASHINGTON
JEFFERSON
EDWARDS
WABASH
MONROE
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PERRY
FRANKLIN
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WILLIAMSON
SALINE
GALLATIN
UNION
JOHNSON
POPE
HARDIN
ALEXANDER
PULASKI
MASSAC
Scale of Miles
10 0 10 20 30 40 50
ILLINOIS STATE GEOLOGICAL SURVEY

Fig. 5. - Generalized map showing those areas where limestone deposits more than 3 feet thick are exposed in places, and indicating the principal characteristics of the limestones.

Legend

Numerous thick deposits of dolomite. Many of these deposits are composed of high-testing dolomite but some are cherty or otherwise impure.

Numerous thick deposits of dolomite; in some places includes limestone deposits mostly less than 30 feet thick. Many of the dolomite deposits consist of high-testing dolomite, but some deposits are cherty or otherwise impure. The limestone deposits in general have a medium to high test; many of them are intermediate in chemical composition between true limestone and dolomite.

Numerous thick limestone deposits. Many of these are composed of high-testing limestone, but cherty and otherwise impure limestones are present in some places.

Numerous thick limestone deposits, of which a large percentage are cherty but test high if the chert is removed. In some places deposits of chert-free limestone are present and range from high-testing to impure. Dolomite deposits, some of them cherty, occur in southern Calhoun and western Jersey counties and in Adams County and the counties farther north. Limestone deposits containing interbedded dolomite strata are also present.

Thick to thin limestone deposits and thick to thin deposits of shale and sandstone. Many deposits of high-testing limestone are present but less pure limestones also occur.

Scattered deposits of limestone or dolomite, mostly less than 30 feet thick and of variable purity.

Numerous thick deposits of chert, cherty limestone, and otherwise impure limestone; includes a few deposits of medium- to high-testing limestone in some places.

Scattered deposits, mostly of "Coal Measures" limestones. In each of the areas mapped, some limestone strata more than 3 feet thick are believed to be present; however, deposits more than 20 feet thick are rare. Purity varies.

No limestone deposits more than 3 feet thick known.

formation has its normal thickness, that is, a relatively constant thickness over a considerable area. Thus if a limestone stratum is consistently 3 or 4 feet thick over a wide area, this may be regarded as its normal thickness in that area. However, if in an adjacent smaller area the same limestone stratum is 9 feet thick, the purity of such abnormally thick deposits is apt to be considerably less than where the bed is 3 to 4 feet thick. It appears that many such increases in thickness result largely from local increases in the amount of clay and silt mixed with the limestone during deposition so that the thickened bed may represent to a considerable degree an enlargement of the normal bed by impurities. The term thickness as used in this paragraph refers to the natural thickness of a stratum which has been unaffected by erosion.

A type of limestone found in the "Coal Measures" rocks at numerous places is commonly described as "nodular" or as "conglomeratic." Especially in weathered outcrops it appears to be lumps of limestone in a matrix of somewhat softer earthy limestone. The LaSalle limestone of LaSalle County and the Lonsdale limestone of Peoria County show this structure at many places. Nodular and conglomeratic "Coal Measures" limestones are of variable purity. Although they may test over 90 per cent C.C.E. they often test about 70 to 80 per cent, mainly because the matrix material contains much clay and silt.

The "Coal Measures" limestones are rarely cherty or dolomitic. Their most common impurities are clay and silt.

Southern and southwestern Illinois. - The Mississippian rocks of southern and southwestern Illinois commonly used for agstone include the Salem, Ste. Genevieve, and St. Louis formations (fig. 3), all of which are more than 100 feet thick. Numerous deposits of these limestones afford suitable quarry sites. The formations are almost exclusively limestone and many deposits are of high purity. Besides these named formations a considerable number of other limestone formations, usually not as thick, also provide acceptable rock for agstone.

Western Illinois. - In western Illinois, especially Calhoun, Pike, and Adams counties, the Burlington limestone formation is the major outcropping limestone of Mississippian age. It is characteristically white or light gray where freshly exposed, often coarsely crystalline, and commonly cherty. It usually has a high C.C.E. if the chert is removed, and it is worked in many places as a source of agstone. It is overlain, especially in Adams County, by a brown cherty limestone or interbedded limestone and dolomite formation of variable purity known as the Keokuk formation.

North of Adams County to the north line of Henderson County, the Burlington limestone crops out in places but younger rocks belonging to Warsaw, Salem, or St. Louis formations are also exposed. These formations are commonly variable in character and many deposits are impure limestone or consist of alternating strata of pure and impure limestone; dolomite beds are present. The Burlington and younger limestones are used for agstone. Although outcrops are relatively abundant, the production of a high-testing agstone is in many places more of a problem than in the other areas of Mississippian rocks.

Northern Illinois. - Dolomites predominate in northern Illinois. In the Chicago, Joliet, and Kankakee areas and in Whiteside County, the Silurian dolomites, especially those of the Niagaran formation, are extensively quarried for agstone. Elsewhere the Galena and Platteville dolomite formations are the principal sources of agstone. In Lee and LaSalle counties another dolomite, the Shakopee dolomite, is also a possible source. For the most part the area wherein these various dolomite formations crop out is well supplied with quarry sites and with dolomite deposits of high C.C.E. value. Cherty dolomite deposits abound in some parts of the region and locally there occur dolomites which are also impure because they have a high content of clay, silt, or sand. The dolomites are usually gray or brown in color, and those which are porous and develop a sandy texture on weathering are likely to test high, although other varieties may also test high. Comparatively minor areas of limestone occur in the northern Illinois area, notably at Dixon where it is used for making Portland cement.

Shell marl and calcareous tufa. - Of relatively minor importance from the standpoint of number of deposits and the quantity of liming material they afford are shell marl and calcareous tufa, also sometimes called "travertine," which are found in some parts of Illinois. The tufas are the relatively unconsolidated deposits made by modern or ancient springs or seeps, and although the amount of tufa available at any one place is generally not large, some deposits are of sufficient size to support comparatively small operations for the production of liming materials. The tufas are composed chiefly of calcium carbonate, and although some relatively pure deposits occur, many deposits test between 75 and 90 per cent C.C.E. and some are even more impure. Impurities are sand, silt, clay, and organic matter.

Figure 6 indicates two ways in which tufa deposits are believed to be formed in Illinois. The left-hand drawing shows rain or snow-water sinking into surface material which is a porous silt. This water percolates into a gravel bed that contains limestone pebbles from which the water dissolves calcium carbonate. The downward progress of the water is stopped, however, by a bed of tight, impervious clay so that the water moves laterally and emerges from the face of the bluff or slope as springs or seeps. As the water evaporates or for other reasons loses its capacity to retain calcium carbonate in solution, the calcium carbonate is left behind and accumulates as the tufa deposit.

The right-hand figure shows a somewhat similar situation except that the water obtains its calcium carbonate from a limy silt and from a limestone bed by moving along the top of the limestone or percolating through joints in it. In both situations, because of the moist conditions resulting from the presence of springs or seeps, organic materials also accumulate and add to the volume of the tufa deposit.

An important point regarding tufa deposits which is not appreciated by many persons is that although the vertical distance from the top to the bottom of a

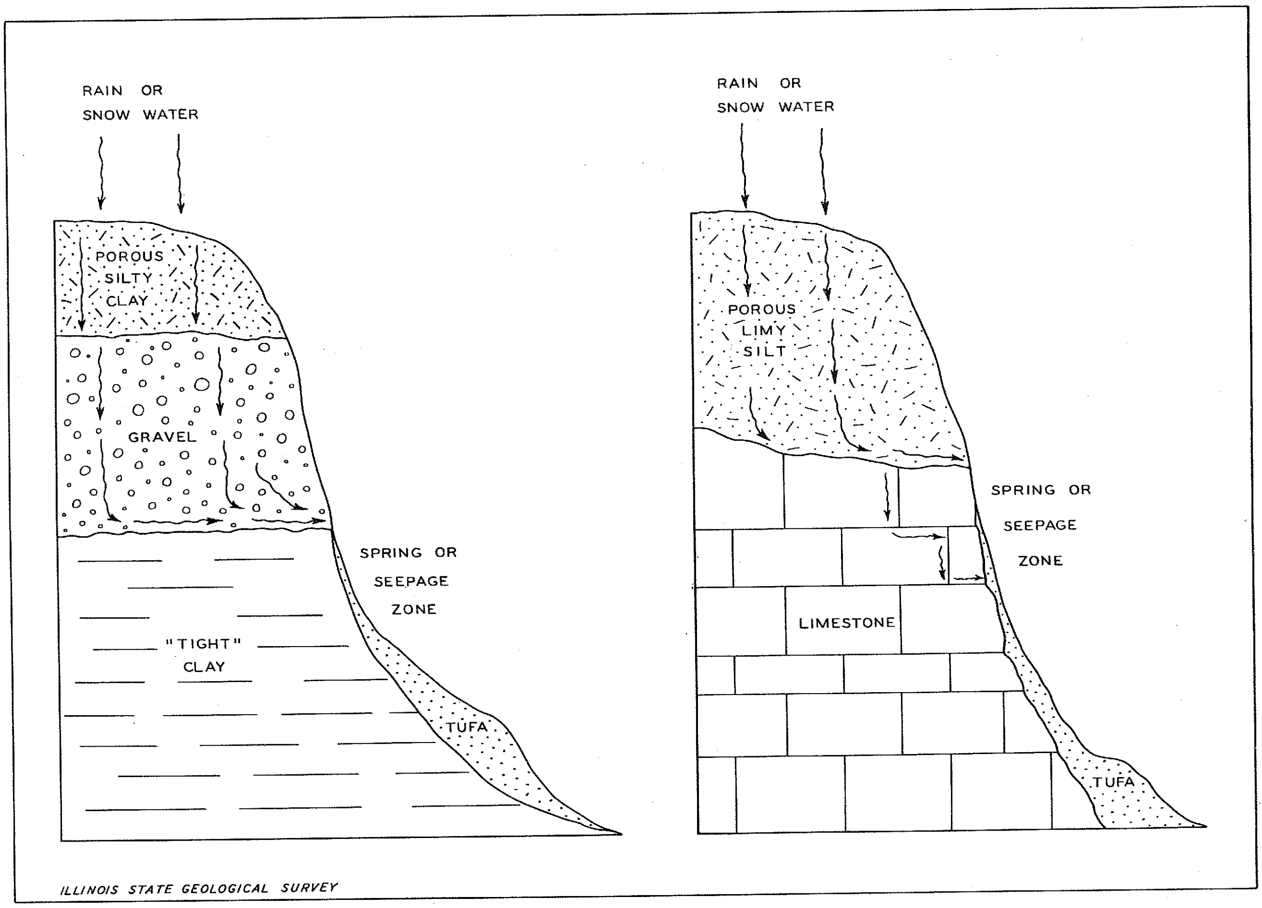

Fig. 6. - Ways in which Illinois tufa deposits may be formed, shown diagrammatically.

deposit may be, for example, 30 feet, this figure does not represent the thickness of the deposit measured in the usual way and cannot be used in the ordinary way for calculating the volume or tonnage of the deposit.

Shell marl, composed principally of small mollusk shells, is found mainly in depressions in the present ground surface that were formerly occupied by lakes. Most of these lakes were formed when the glaciers retreated from Illinois. Marl is commonly associated with peat or muck; many marl deposits are overlain by or are mixed with these materials. Thickness and purity are highly variable.

Other Limy Earth-materials in Illinois

Besides limestone, dolomite, shell marl, and tufa, there are in Illinois a number of other limy earth-materials which require brief mention because inquiry is frequently made regarding them as liming materials. They are described below.

Glacial till is a pebbly or bouldery clay which covers practically all of the State except the extreme northwestern and extreme southern parts. It was deposited by the glaciers which once spread over most of Illinois. When fresh it is gray or blue-gray but it turns brown upon exposure to the weather. Some of the pebbles in the clay are limestone or dolomite and the clay itself is likewise limy. Obviously the number of limestone or dolomite pebbles in the glacial till and the extent to which it has been weathered will greatly affect its test, but it is unusual for till to test over 50 per cent C.C.E. and usually it tests between 10 and 30 per cent.

Glacial silts containing limy material are found at many places in Illinois, especially in the northern half. Some deposits occur as layers or irregular masses overlain and underlain by glacial till, others are associated with gravel deposits, and still others comprise fairly extensive and thick deposits occupying the basins of extinct glacial lakes. The silts vary greatly in character but the variety most commonly inquired about as a liming material is a very fine-grained gray or brown silt which when dry is easily pulverized to a flour in the fingers. Such silts contain some sand but no pebbles, although they may contain pebble-like pellets or irregular masses of silt cemented by calcium carbonate.

The glacial silts rarely test over 40 per cent C.C.E. when fresh and unweathered and it is believed they more commonly test between 15 and 30 per cent C.C.E.

Loess is a wind-deposited silt found in many parts of Illinois, especially in the western half and elsewhere in areas adjoining major rivers. It is gray when fresh but weathers brown. The fresh unleached loess is limy and in places contains pellets or irregular masses of silt cemented by calcium carbonate. The total carbonate content is not high however. It has a maximum C.C.E. of about 30 per cent and commonly has a value between 5 and 20 per cent.

Limy sandstone is sandstone cemented by calcium carbonate. Where freshly exposed such rock has a glassy appearance and gray color not unlike some limestones or dolomites and is very hard to break. When weathered it becomes brown, and careful examination of the surfaces of weathered pieces usually will show an abundance of sand grains indicating the sandy character of the rock. There are all gradations between limy sandstone and sandy limestone or sandy dolomite with accompanying variations in C.C.E. value. However, limy sandstones generally cannot be regarded as favorable materials for making agstone because the sand they contain is highly abrasive to crushing equipment and only in unusual circumstances is it probable that high wear would not make the cost of crushing prohibitive.

Limy sands are found in many parts of Illinois. In the northern fifth of the State there are scattered deposits of sand made up of dolomite grains resulting from the decay of dolomite rock. Such deposits afford high-quality liming materials, but they are relatively rare. Generally the common sands of the State consist principally of the mineral quartz with lesser amounts of feldspar and other minerals. The C.C.E. values vary greatly. Some sands contain no carbonates. Probably the ordinary maximum is about 60 per cent C.C.E. and in general the value is believed to be below 40 per cent. The common sands of northern and northeastern Illinois will in many cases test higher than those of other parts of the State, but there are great variations between deposits in all parts of the State and no average figure or range for C.C.E. can be set up.

<u>Gravel</u> deposits containing pebbles, cobbles, and boulders of limestone and dolomite are common in many parts of Illinois. These gravels are of glacial origin. They were sorted out and laid down by waters resulting from the melting of the glacial ice in which they were originally embedded along with clay and silt. The amount of limestone and dolomite in the gravels varies greatly, but in general it is believed that the gravels in the north half of the State and especially in the northeast quarter are apt to contain more of these rocks than the gravels in other parts of the State. Not only does the amount of limestone and dolomite vary from one deposit to another, but it also varies according to the size of the rock fragments comprising the gravel. In general, the available data indicate that limestone and dolomite content usually increases with the coarseness of the gravel; thus gravel between 1 and 2 inches in size is likely to contain more limestone and dolomite than does gravel between 1/2 and 1 inch in size.

Studies of the pebbles which went through a screen having a 1-inch opening but caught on a screen having 4 openings or mesh to a linear inch (the size of the opening is about 1/5 inch) from 17 northeastern Illinois gravel deposits indicate a C.C.E. value ranging from 65 to over 90 per cent and an average of about 85 per cent. Probably the pebbles and other fragments coarser than 1-inch would test even higher in most cases. However, the material which will pass the 4-mesh screen usually will have a lower test, and in the case of the 17 samples mentioned above, it ranged from 40 to 70 per cent C.C.E. and averaged about 60 per cent.

As may be surmised from the foregoing, the glacial gravels are comprised of considerable amounts of materials other than limestone and dolomite. The material passing the 4-mesh screen, that is the sand, contains abundant grains of the mineral quartz. The pebbles, cobbles, and boulders of the gravel include many varieties of igneous rocks, such as granite as well as more or less chert. Many of these igneous rocks contain an abundance of the mineral quartz and all of them contain other minerals that are considerably harder than limestone or dolomite. As a result of the presence of the quartz, chert, and other hard minerals the crushing of gravel to a fineness suitable for agstone is apt to result in high abrasion to crushing equipment of the type usually employed for this purpose. Under some circumstances hand-picking of limestone and dolomite cobbles and boulders from gravel being produced for other purposes might be a feasible way of obtaining a material for making agstone, but in general it is doubtful if Illinois gravel deposits can be regarded as likely sources of agstone under usual conditions.

Examination of Limestones and Dolomites in the Field

The average person who is familiar with agstone usually has little difficulty in distinguishing limestone or dolomite from sandstone or shale. However, to distinguish between limestone and dolomite in the field is often troublesome and sometimes impossible. There are, however, certain clues that are useful. If dilute hydrochloric acid, also known as muriatic acid, is applied to a freshly broken surface of a piece of limestone, it causes vigorous effervescence immediately. When applied to a freshly broken surface of a piece of dolomite, however, the acid produces only a slight or mild effervescence which is often slow in beginning, especially if the surface has been freed from stone dust by blowing upon it or washing it. A large amount of impurities in a limestone tend to reduce the vigor of the effervescence produced by the acid and so some impure limestones may be confused with dolomites. Hot acid reacts vigorously with either limestone or dolomite.

Another test which is helpful, although not infallible, in distinguishing between limestone and dolomite depends on the fact that dolomite usually contains a small amount of ferrous iron rather uniformly distributed through it whereas limestone does not. The test is often referred to as the potassium ferricyanide test. A small quantity of a solution of this chemical prepared as indicated below 1/ is applied to the surface of the rock to be tested. A blue stain usually appears promptly. If the blue stain persists after the rock has been washed thoroughly under a mild stream of water from a faucet, but not scrubbed, the specimen is probably dolomite. Thorough washing and a permanent stain are critical items in this test. Small scattered deposits of the blue color in holes in the rock specimen or in the cracks between the grains or crystals are not usually significant.

A great many specimens of Illinois dolomite have been tested in the above manner and almost invariably the blue color becomes apparent within five minutes or less but a few require as much as half an hour to develop a good blue color.

Weathered outcrops of Illinois dolomite are commonly brown or buff, the rock is often porous, and many weathered exposures appear to have a sandy surface. When thoroughly weathered, dolomite may disintegrate to a sand or to a relatively soft "punky" rock. Weathered Illinois limestones, however, rarely develop a sandy surface or form a calcite sand, their exterior surfaces may be brown, usually yellowish-brown, but this coloration commonly does not penetrate deeply into the deposit, and they are ordinarily not highly porous, as seen by the naked eye.

It is difficult to lay down rules by which the average person can judge by examination with the naked eye the approximate purity of a limestone or dolomite.

1/ The potassium ferricyanide solution is prepared as follows: To 7 parts by volume of distilled water add 3 parts by volume of C.P. hydrochloric acid. Mix thoroughly and add enough solid potassium ferricyanide to produce a strong orange-yellow color when dissolved. Keep in a rubber- or glass-stoppered bottle.

However, in general, dull earthy appearing limestones and dolomites which flake, chip, or crack badly when exposed to the weather are apt to be impure. On the other hand, crystalline limestones which withstand the weather well are likely to be relatively pure. The porous varieties of dolomite and those which develop a sandy exterior are usually relatively pure but other varieties may also be pure. Obviously, clay partings in either limestone or dolomite are likely to indicate a deposit of questionable purity.

Free silica in agricultural limestones is also important because most forms of this material are abrasive to crushing or grinding equipment. It occurs as chert or "flint", as sand grains, and as smaller particles of silt or grit. The sand and silt are composed of the mineral quartz; the chert is also composed principally of minute quartz crystals. Chert and sand are recognizable to the naked eye or with a magnifying glass, but estimates of free silica intended to include the silt particles are best made with a microscope or by other means.

Various figures have been reported as to the amount of free silica which limestone or dolomite to be used for making agstone may contain without seriously damaging the crushing and pulverizing equipment. The most common figure is "less than 3 per cent." The fact remains, however, that at a number of places in Illinois, limestones containing more than 3 per cent free silica are being made into agstone and no greatly abnormal wear to the equipment is reported. This matter is worthy of more study, but abrasiveness of a limestone may well be related both to the amount of free silica present and the natural hardness of the limestone.

Evaluation of Quarry Sites

The examination of limestone or dolomite outcrops from the standpoint of their suitability as sites for agricultural limestone quarries involves a number of obvious aspects which do not need special consideration here, such as accessibility to roads, markets for the agstone, possibility of flooding by overflow from creeks, and the like. There are, however, three other matters which merit discussion - namely, thickness and character of deposit, overburden, and methods of sampling.

Thickness and character of the deposit. - The thickness of a deposit is especially significant in connection with the "Coal Measures" limestones and other relatively thin limestones underlain by clay or shale. Limestone strata of this kind are likely to be jointed, and if they occur in a hillside or bluff, blocks of the stone often break loose and slide down the slope which thus becomes strewn with limestone blocks. It is very easy to interpret this as an indication of a thick limestone deposit, whereas actually the source bed may be only a few feet thick. Therefore, it is well to disregard loose blocks or masses of limestone in estimating thickness and attempt to base such estimates only on layers which are definitely in their original position. This same statement applies to thin dolomite beds.

Another situation requiring careful consideration is that of thin limestone formations cropping out in creek beds. Such situations are most common in that part of the State underlain by the "Coal Measures". Though outcrops of this type may be traceable for considerable distances along a creek channel, it is not necessarily true that the entire flood-plain is underlain by the limestone, as over considerable areas in the flood-plain or valley flat the creek may have worn away the limestone entirely or may have made the bed too thin to be profitably quarried. Therefore, prospecting by test-drilling or test-pits should precede attempts to develop such deposits on a scale of any magnitude.

Overburden. - Overburden is another problem in connection with many deposits. Where thick limestone formations are available considerable tonnages of stone can usually be obtained without developing quarries of very great area, by quarrying along the edges of outcrops, where overburden is commonly thin. Where limestones are thin, however, especially where they are less than 10 feet thick, the production of large amounts of stone requires quarries of relatively great lateral extent, and thickness of overburden is therefore a much more critical factor. Commercial quarrymen operating in such deposits state that it is not economically feasible to move an average of more than one foot of overburden to uncover one foot of stone, or, in other words, it is not practical to remove a greater average thickness of overburden than the average thickness of the limestone thus uncovered. Actually a few quarries have been observed where almost 1 1/2 feet of overburden was being removed for each foot of limestone uncovered, but this seems to be about the maximum for the average small or medium-sized agricultural limestone quarry.

The character of the overburden is also important. Bedrock materials, such as shale or sandstone, are normally more difficult to remove than are clays, silts, or sands. The figures given above regarding economically removable thicknesses of overburden apply to these surface materials. The figure would be less for shale and sandstone.

Methods of sampling. - Sampling of a limestone or dolomite deposit to determine its C.C.E. is a critical operation. It is particularly susceptible to the personal variable. For example, just what 2-pound piece of rock should be taken for a C.C.E. test from a 10-foot outcrop of limestone is, as a rule, a matter of considerable question. Actually it is generally not possible to sample a limestone or dolomite deposit satisfactorily in this way because the various strata comprising a deposit are likely to vary in composition and even single layers 2 feet or less in thickness may vary from top to bottom.

As an actual case in point, a deposit of "Coal Measures" limestone comprising three outcrops was being considered as an agricultural limestone quarry site. Three different samples about the size of a fist had been tested from this deposit and showed 58, 73, and 91 per cent C.C.E. The person submitting the samples was inclined to question these tests because of their divergence. Not until the deposit was

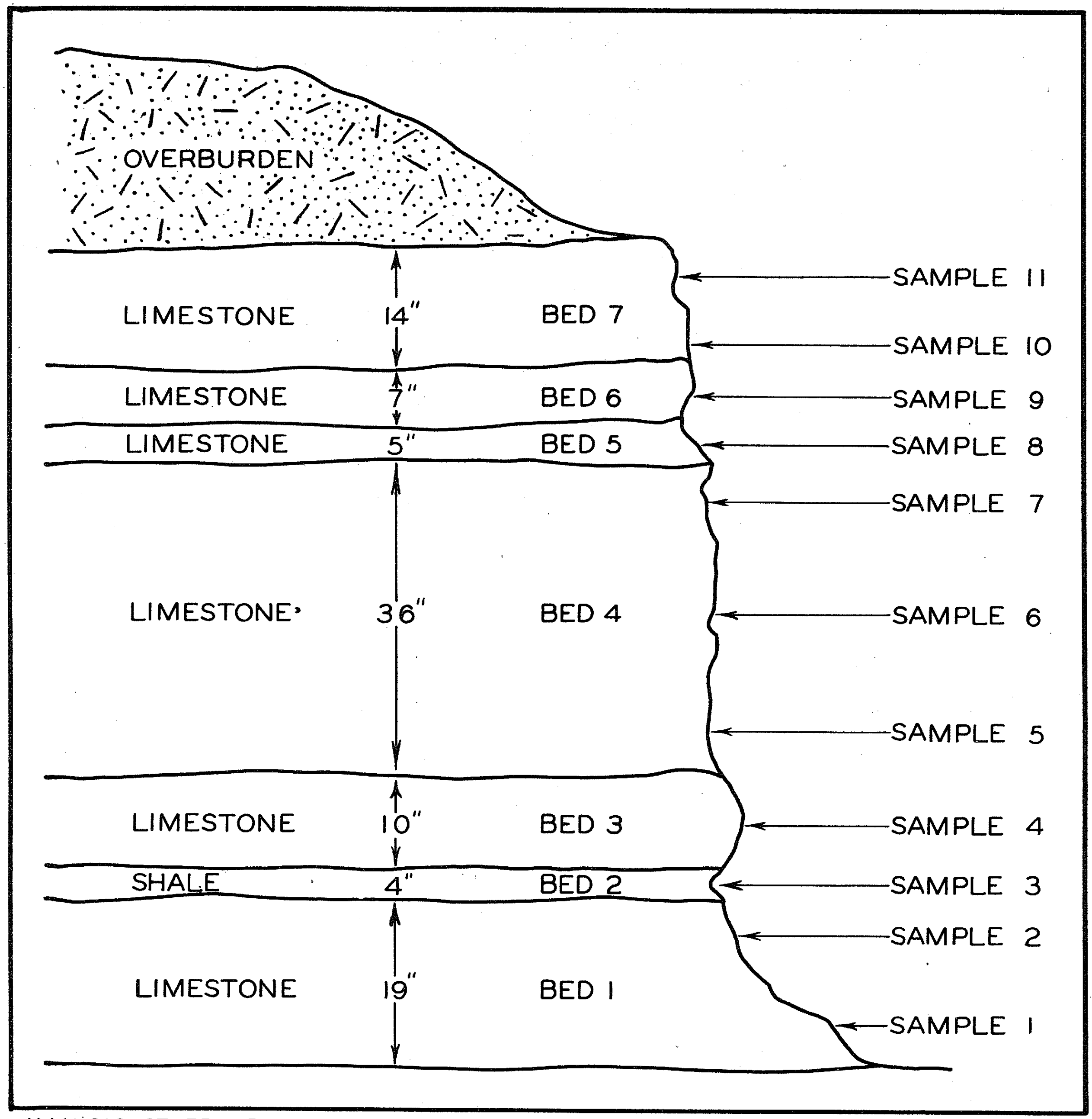

Fig. 7. - Suggested method for sampling limestone and dolomite deposits.

adequately sampled and these later samples tested was it revealed that there was actually a variation of from 46 to 91 per cent in the C.C.E. values of the various beds in the 9-foot deposit.

To avoid possible misleading results from samples, therefore, it is wise to take samples according to a definite plan, leaving as little as possible to personal choice. A satisfactory method for doing this is to take a sample from each vertical foot of the outcrop, or from each bed as indicated in figure 7, the principal object being to obtain a series of samples such that all variations in the deposit will be represented. Care should be taken to include samples of clay or shale partings for if such are present they are obviously likely to reduce the C.C.E. of the deposit as a whole.

The results of C.C.E. tests on samples taken from outcrops or rock faces are generally 2 to 5 per cent higher than the C.C.E. of the finished agstone produced by the usual quarrying methods. The fact that a certain amount of dirt becomes mixed with the stone during quarrying accounts for this difference but good quarrying technique can keep it to a minimum.

Underground Mining to Avoid Overburden

The problem of overburden in agricultural limestone quarries is commonly solved by stripping off the overburden, as has been mentioned. Another solution to this problem is to leave the overburden and to produce the stone by underground mining methods. Not only does this avoid the necessity of stripping but also it permits selective mining of high-quality strata. This is particularly significant in quarries yielding agstone having a relatively low test because the deposits being worked contain layers of impure stone associated with layers of high quality stone, and it is not economical to eliminate or avoid the impure stone in quarrying.

A great many factors are involved in the question of whether a limestone or dolomite deposit is adapted to underground mining, but of primary importance are a good roof and floor. Shale, clay, sand, and gravel, would not normally make good roofs. Also when serving as either roof or floor they would be a possible source of impurities which would contaminate the agstone. A well cemented sandstone might be a suitable roof or floor under some circumstances, but a solid limestone or dolomite bed several feet thick is ordinarily apt to be the most satisfactory.

Without doubt underground mining is practical in the thicker limestone or dolomite deposits, inasmuch as it is actually practiced at a number of places in Illinois by some of the larger stone-producing companies. One of the thicker "Coal Measures" limestones and several of the thick limestones of the Mississippian and Ordovician systems have been or are being mined commercially. However, in most places underground mining of the thin limestones of the "Coal Measures" and of other systems is apt to be of questionable practicality at present, principally because these thin beds commonly have unsuitable roofs and floors. Such a procedure for these thinner beds cannot be ruled out entirely, however, as under some circumstances economic conditions might in places justify underground mining.

Work of the State Geological Survey on Resources

The Illinois State Geological Survey, with offices and laboratories in the new Natural Resources Building, University of Illinois campus, Urbana, Illinois, has for many years been accumulating data regarding the limestone and dolomite resources of the State. A large fund of information has been assembled regarding the location of outcrops and their actual or probable character and thickness. Many samples have been tested and the results afford information regarding the composition of the limestones and dolomites available for agstone in almost all parts of the State. Special intensive studies have been conducted in selected counties wherein the need for agstone is great and the local agricultural limestone resources were little known or not generally appreciated. The crushing characteristics of selected limestones and dolomites are being investigated to determine which formations are most suitable for agstone. The Survey is prepared to give assistance and advice regarding resources and quarry sites, and to make preliminary tests on samples from deposits in which there is a genuine interest as potential sources of agstone. In short, it is the aim of the Survey to assist and cooperate in the utilization of the limestone and dolomite resources of Illinois so as to maintain and increase the fertility and productiveness of the farms and pastures of our State.

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