THE FERTILIZER MATERIALS OF IOWA.

by

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FERTILIZERS

When one applies fertilizer to the land he is trying to supply one or more of three elements in a soluble form or to supply something that will change the elements already present but unavailable to the soluble form so that plants may use them or that they may act as reagents. These elements are nitrogen, phosphorus and potash. In recent years it has been found in some states (Oregon, e.g.) that sulfur when used as a fertilizer serves to improve the growth of alfalfa. Some of these and possibly other elements may aid vegetable growth in various other ways than by supplying plant food directly.

The materials considered in this work for the purpose of determining their value as fertilizers are peat, lake salts, gypsum, marl, pyrite, phosphates, limestone and dolomite. The fertilizer value in peat is found chiefly in its organic matter, nitrogen, phosphate and sulfur; that of gypsum, in its content of calcium sulphate and in its effects where it is used; that of marl, limestone and dolomite, in their calcium carbonate, magnesium carbonate and phosphate and in their chemical, physical and biological effects where they are used.

Potash

Several reports saying that certain Iowa lakes contained deposits of potash have been circulated. One of these emanated from the vicinity of Goose Lake in Greene county where samples were obtained for analysis at Iowa State College at Ames. The analytical tests which were made failed to show the presence of potash.

Since potash in lakes is found only in salt lakes and in arid and semiarid regions, it is useless to search for it in fresh water lakes in a state having the abundance of rainfall that is common here.

Gypsum

Many years ago most of the gypsum mined and quarried was used as a soil amendment but during the past decade only a

small part, about three per cent of the output of the United States, has been so used. Recently it has been learned that one of the uses of gypsum when put on soil is to supply sulfur, which is now used on some crops, such as alfalfa, in some states. An exhaustive treatment of Iowa gypsum may be found in reference 63 recently issued by the Iowa Geological Survey. Iowa gypsum produces a high quality of "land plaster".

Pyrite

This name is used for two closely related sulfides of iron—pyrite and marcasite. Where it is pure and abundant, this mineral is used to some extent in the fertilizer industry. In Iowa it is most commonly found as a brassy-looking mineral in coal and is known as "sulfur" by many and also as "fool's gold".

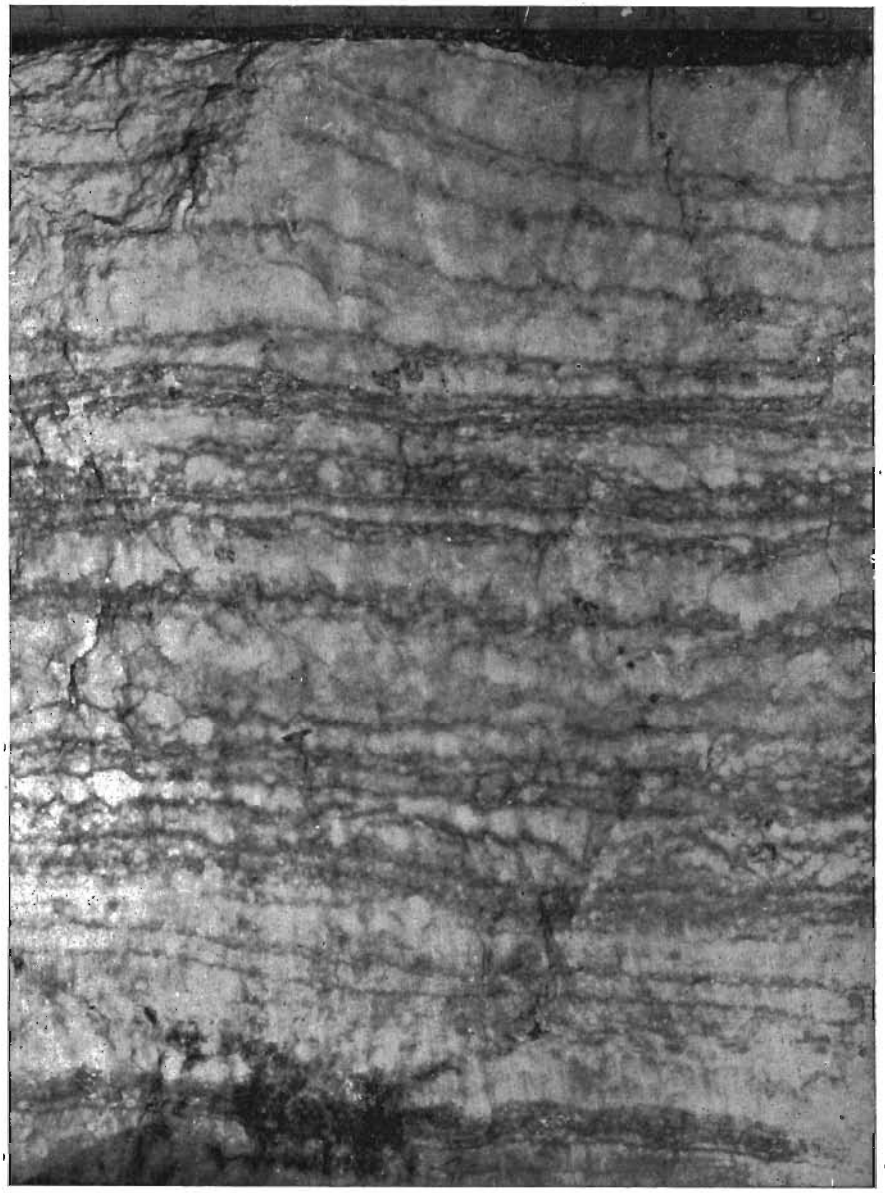
Investigations conducted during a long period of years in the department of mining engineering at Iowa State College show that it is impossible to separate the pyrite from the coal on a paying basis.

Peat

Methods of procedure.—Samples of peat were taken from representative locations in nearly every county in the area of the Wisconsin glacial drift. These were analyzed in the department of chemistry at Iowa State College. Tests having previously been made on Iowa peats for their fuel value, (ref. 15) it remained to test for possible value as fertilizer. The content of nitrogen and of phosphate was determined in each sample with the results as tabulated on page 102.

Though Iowa peat easily catches fire in the bog and burns slowly for weeks or even months it does not burn well enough to be used as a fuel where much heat is needed.

Uses of peat land.—Many of the areas covered with peat are lying as waste land, but some have been drained and are being used successfully as truck gardens which produce various kinds of vegetables for the market. Large areas in the northern counties of the state devoted to a single crop have been successful in growing excellent yields of potatoes and sugar beets of



FORT DODGE GYPSUM. VIEW SHOWING ITS BANDED STRUCTURE.

high quality. This suggests a possible use as an enrichment for other land.

USES OF PEAT.

As fertilizer.—In Europe peat is used chiefly for fuel but in America its principal importance is due to its value in the fertilizer industry. The manufacture of filler for chemical fertilizers requires the major part of the domestic product. Black, thoroughly decayed peat is considered better than the more fibrous brown types for this purpose. This use of peat is growing in favor.

Inoculated peat.—To increase its percentage of nitrogen, peat is now being inoculated with nitrifying bacteria. Inoculated peat is used for fertilizer in England, and in the United States commercial quantities have been manufactured and sold to a very small extent. Four per cent of nitrogen is reported in peat that was inoculated after repeated treatment with a dilute solution of ammonium sulphate.

Other uses.—Peat is also mixed with molasses and made into a stock food. About seven per cent of the peat produced in the United States is used in this way. Those varieties of peat which are fibrous are used as bedding for animals and for packing. The fine material sifted from moss litter by screening is known as "mull" and is used for deodorizing, disinfecting, filtering and also for packing. Some of the fibrous peats can be used in the manufacture of cloth and paper.

Analyses of peat.—The table below gives the locations from which samples of peat were procured for analysis and also the percentage composition of nitrogen, and of phosphate expressed as P_2O_5. Nearly all samples of peat contain small amounts, about one-half to one per cent, of sulfur. See the map (Pl. IV) opposite page 102.

Analyses of Iowa Peat.

County	*Township*	*Lab. No.*	*Section*	*N. Per Cent*	*P_2O_5 Per Cent*
Boone	Colfax	41	SE. ¼ of NW. ¼ of 34	2.37	0.78
Boone	Yell	44	NE. ¼ of SE. ¼ of 32	2.40	0.45
Calhoun	Sherman	46	SW. ¼ of 32	1.39	0.50
Emmet	Iowa Lake	68	NW. ¼ of NW. ¼ of 4	2.25	0.69
Greene	Bristol	45	SE. ¼ of SE. ¼ of 1	2.29	T
Hamilton	Lyon	21	SE. ¼ of NW. ¼ of 32	1.71	0.649 W
Hamilton	Lyon	22	SE. ¼ of NW. ¼ of 32	2.08	0.525 W
Hamilton	Rose Grove	63	SE. ¼ of 23	2.38	0.53
Hancock	Garfield	62	NW. ¼ of 30	2.43	0.48
Hardin	Concord	69	Line bet. 25 and 36	2.08	0.64
Story	Palestine	42	SW. ¼ of 22	1.34	0.78
Story	Franklin	43	SE. ¼ of NW. ¼ of 36	1.61	0.50
Webster	Dayton	47	NE. ¼ of SW. ¼ of 6	1.78	0.41
Winnebago	Center	65	NE. ¼ of 15	2.71	0.87
Winnebago	Center	66	NW. ¼ of SE. ¼ of 36	2.90	0.87
Winnebago	King	67	NW. ¼ of NE. ¼ of 26	1.50	0.81
Worth	Fertile	32		2.15	0.531 W
Worth	Fertile	33		2.16	0.486 W
Wright	Lake	61	NE. ¼ of NE. ¼ of 1	2.59	0.63
Wright	Blaine	64	NW. ¼ of NW. ¼ of 35	1.88	0.57

Analyses in the above table marked W were made by E. H. Wallace; those unmarked are by H. E. Flanders. These analysts are in the department of chemistry at Iowa State College.

DESCRIPTION BY COUNTIES.

The locations of peat bogs, their relative importance and their relation to the various morainic deposits (tentatively located) are shown on the accompanying map, Plate IV, which is based on incomplete field work. There has recently been a reassignment of names to some of these moraines. (Ref. 68.)

Boone County.—Boone county is in the middle of the southern extremity of the Gary moraine, which reaches its maximum development in the north-central part of the county. Here very little peat is found but in the western part of the county, where the moraine covers a wider tract, peat bogs have developed among the hills. In the southern half of the county, smaller but more numerous bogs are found scattered among the smaller recessional knobs and undulations.

Sample number 41 was collected from a ten acre bog of brown fibrous peat about three miles southwest of Napier. Though the bog does not exceed eighteen inches in depth, it is fairly typical of a number of small bogs in southeastern Boone, in northern

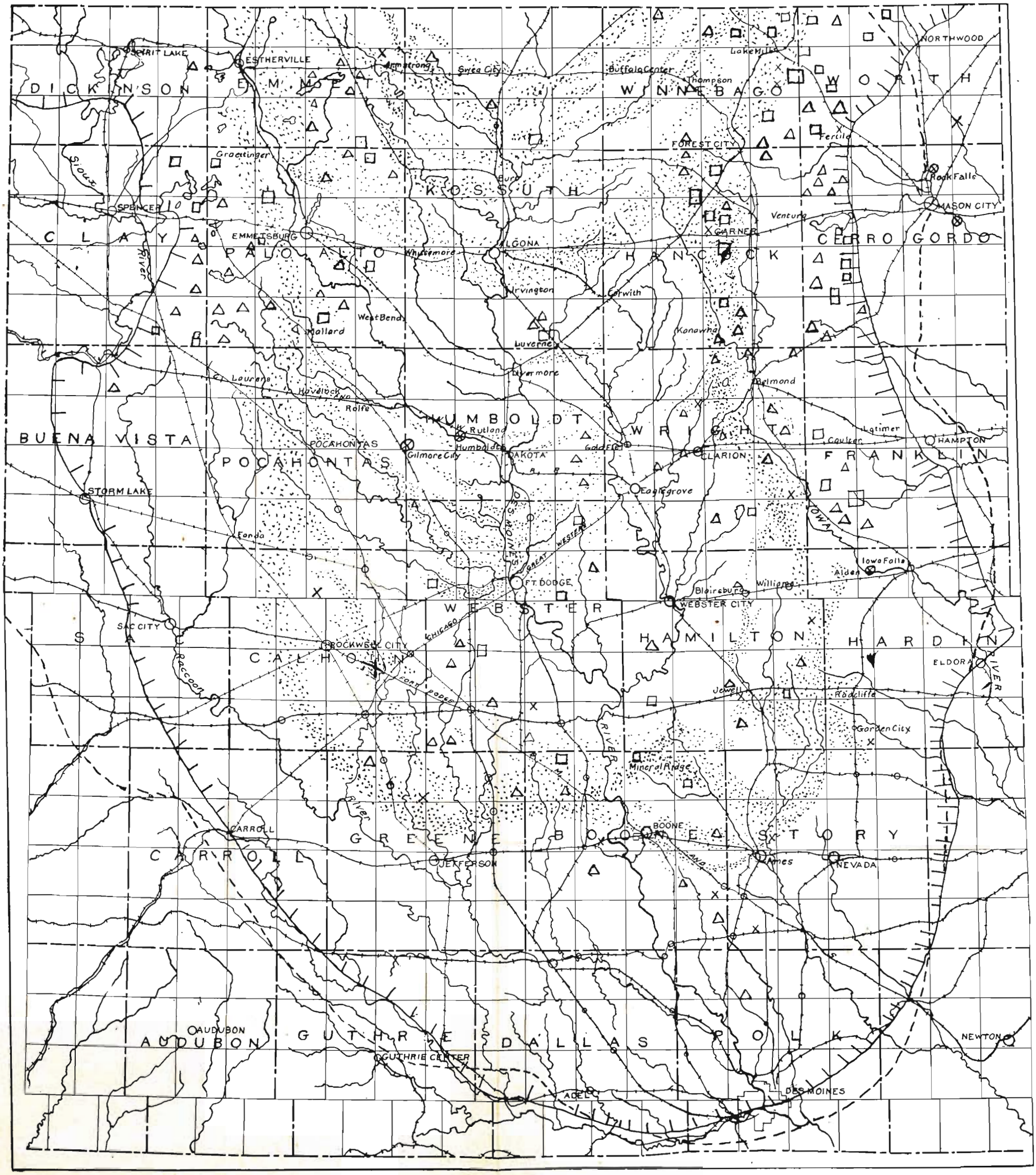


PLATE IV.—A PRELIMINARY MAP OF THE WISCONSIN GLACIATED AREA IN IOWA. LINE OF DASHES SHOWS BORDER AS DETERMINED BY THE IOWA SCIL SURVEY. THE RECESSIONAL MORAINES—THE GARY, HUMBOLDT AND ALGONA STAGES—ARE SHOWN IN DOTTED AREAS. OPEN SQUARES SHOW LOCATION OF IMPORTANT PEAT BOGS; TRIANGLES, LOCATION OF SMALLER BOGS OR GROUPS OF BOGS; X SHOWS LOCATIONS FROM WHICH SAMPLES WERE OBTAINED FOR ANALYSIS, EXCEPT NORTHEAST OF MASON CITY WHERE IT SHOWS TESTED OUTCROP OF LIMESTONE; X WITHIN CIRCLE SHOWS LOCALITIES PRODUCING AGRICULTURAL LIME. THERE HAS RECENTLY BEEN A REASSIGNMENT OF NAMES TO SOME OF THESE MORAINES (REF. 68).

Polk, and in adjacent parts of Dallas and Story counties. The triangles shown on the map represent a number of bogs in each locality.

Sample number 44 was selected from a drained bog, (fig. 8) near the Chicago and North Western railway about one mile east of the city limits of Ogden. The specimen consists of brown fibrous peat ranging from two to three feet in depth. Some of the plant ingredients of the rush type are remarkably well preserved. The bog lies between minor recessional deposits.

Calhoun County.—A bog located about half a mile west of the south end of North Twin Lake supplied the sample studied as

FIG. 8.—A drained peat bog east of Ogden, Boone county. The peat is two to three feet thick.

number 46. The material is a very dark brown to black peat showing very little of the fibrous character. Some of it is well rotted. Several small bogs occur in this part of the county among the hills of the smaller moraines.

Cerro Gordo County.—The outer margin of the Wisconsin drift sheet extends nearly north and south and passes less than a mile east of the city of Clear Lake. From this margin westward there are several bogs in each township of the Wisconsin drift area, which includes all of the western tier of townships in the county.

Emmet County.—Very little peat is found in the western part of the county among the larger, higher moraine hills. The area from the river eastward lies wholly within the Algona recessional stages of the Wisconsin ice sheet and here a large number of bogs have formed. The sample analyzed, number 68, was taken from the large bog about three miles north of Armstrong in Iowa Lake township and about a quarter of a mile east of the school house. (See map, Plate IV, and table, page 102.) This bog covers approximately a thousand acres and has depths of three to nine feet with an average of about four feet. It lies between minor recessional ridges. This peat is fine in texture and is brown to nearly black.

Other important areas are found within two or three miles northwest and southeast of Gridley; about the same distances east and south of Halfa; about four miles southwest of Ringsted; a mile or more north and south of Swan Lake; and within two miles east of Mud Lake. Each triangle on the map represents several bogs. The chain of lakes drained by Jack creek seems to occupy a partly filled preglacial valley or other depression. The depressions containing the peat in this part of the county may trace their origin in part to the same cause but are due chiefly to unequal deposition of the glacial till.

Franklin County.—Most of the county west of a line drawn from Clear Lake to Ackley through Hampton is covered with Wisconsin glacial till and the bogs are all in this area. Several are located in Oakland township north and northeast of Burdette. These range in size from forty acres to two hundred acres and in depth from two to eleven feet. One of them extends along "Big Slough" from sections 35 and 36 in Morgan township through section 1 of Oakland and into section 6 of Lee township. Other bogs occur in Scott and Morgan townships as is shown on the map. The bogs of this county are very intimately associated with the best developed ridges of the moraines.

Greene County.—The Goose Lake area is the largest in the county. It lies just within the inner margin of the Gary moraine some eight miles northwest of Jefferson. Sample 45 was taken about 300 yards from the south end of the lake. Most of the peat is brown and fibrous, though some of it is nearly black and

well decayed. It is about eighteen inches thick. Figure 9 gives a view of the lake before it was drained.

Hamilton County.—The largest area in the county, containing about 700 acres, is in the bed of the former Iowa Lake, four miles south and two miles east of Williams. It is nestled among the foothills and swells of the inner margin of the Gary moraine which is so prominent as a range of hills along the boundary between Hamilton and Hardin counties. Sample 63 was taken from the bog about 100 yards north of the highway which crosses

FIG. 9.—Goose lake, Greene county, showing some of the kinds of vegetation that enter into the composition of its peat.

its southern extremity. A depth of three feet was penetrated without reaching the bottom. The peat is dark brown, fibrous and lumpy.

A number of bogs aggregating nearly 1000 acres lie to the northwest and southwest of Jewell and within a radius of five miles of the city. The largest one of these is one and one-half miles west of Jewell and is known to extend to a depth of fifteen feet or more. Specimen 21 was dug near the northern margin of the bog but south of the North Western track and number 22 came from a spot farther out toward the center of the bog area. The higher phosphatic content of the former sample, as shown in the table, suggests that it may be from a guano by feathered

inhabitants of the lake margin. The peat is brown, rather finely fibrous but not well rotted.

Each of the triangles shown near Jewell, Stratford and Stanhope on the map, Plate IV, indicates a group of several bogs. Some of the bogs in the county are found to be almost completely surrounded and underlain by a clay soil. Such an area in the ground moraine is located two and one-half miles southeast of Ellsworth and another may be found two miles northwest of Stanhope. Among the bogs on clay soil in the moraines may be mentioned that on the township line in section 4, Lyon township, five miles north of Jewell, and those in the central and northeastern part of section 23, Lincoln township.

Hancock County.—Between Britt and the margin of the Wisconsin glacial drift east of Clear Lake there are six or more well separated groups of recessional hills, ridges or ranges. The sample analyzed as number 62, a brown fine-grained, compacted peat, came from a bog about one mile west of Duncan and north of the paved highway, in a southward extension of the Eagle Lake depression. This lies between the first and second recessional ranges eastward from Britt, which are here about two miles from crest to crest. The large bog two miles south of Duncan is between the second and third of these ranges.

Hardin County.—Except in small areas chiefly in the western part, Hardin county is too well drained to afford conditions favorable for the accumulation of vegetable material and its preservation in the form of peat. The amount in the county is, therefore, not large. From a bog in sections 25 and 36 of Concord township, about three and one-half miles southeast of Garden City, sample number 69 was obtained. This is outside of the Gary moraine. The peat is black to dark brown, partly fibrous and partly decayed.

Polk County.—A number of small bogs are found in the upland area from Ankeny and Enterprise northward and northwestward past Polk City to the county line. In this area the retreat of the ice margin was sufficiently rapid and uniform to produce a somewhat irregular undulating surface whose small, low hills and broad swells are disposed in rather poorly defined recessional belts, which contain the bogs.

A large area of peat land, well drained, is located about two miles west of Herrold near the county line. It lies in a swampy area of the large, partly filled, interglacial valley of the old Moingona river and is extensively cultivated as a truck garden. Several smaller bogs are found along this old valley, some of them nearly as far south as the Fair Grounds where it joins the present valley of Des Moines river.

Story County.—Being situated well southward in the Wisconsin area, and chiefly outward from the Gary moraine, Story county has a relatively small area of peat land. The bogs of the county may be classified in three groups: those in the well defined moraines, which include most of the northern and eastern townships; those smaller bogs of the upland located as described for Polk county but continuing on to the north; and those of the valley bottom type.

Sample number 42 was collected one and one-half miles west of Huxley and represents the black, well decayed peat of the upland bogs. Sample number 43 is a valley bottom peat from a six foot bed about one-fourth of a mile up an unnamed tributary of Skunk river northeast of Ames. Each of the triangles placed on the map, Plate IV, signifies an aggregate of several small bogs.

Palo Alto County.—Peat is found in every township in Palo Alto county. Those containing bogs of large size or having several smaller ones that aggregate a large area are Independence, Nevada, Ellington, Booth, Lost Island, Emmetsburg and Walnut. More than 90 per cent of the peat land of the county lies within areas of distinctly morainic topography. Where moraines are in well defined ridges or ranges of hills, the bogs are located in depressions between them but where the moraines consist of a belt of hills and undrained depressions, the bogs are found to be irregularly distributed throughout the belt.

Webster County.—Here are afforded excellent examples of peat areas developed on the generally flat ground moraine. Nearly all of the bogs in the southwestern part of Webster county are of this type and are located wholly within an area of clay. The largest one, which covers about 1000 acres, is about four miles northeast of Harcourt and from here sample number

47 was obtained. It represents a black, fine, fairly well decayed peat which has a maximum thickness of three feet although much of it is not more than two feet thick. A characteristic feature of most of the bogs of the county is that they are shallow because of having been formed on a relatively flat surface. Each of the triangles shown on the map represents an aggregate of small areas.

Winnebago County.—Nearly all of the peat of Winnebago county lies in its eastern half, which is a region of distinctly

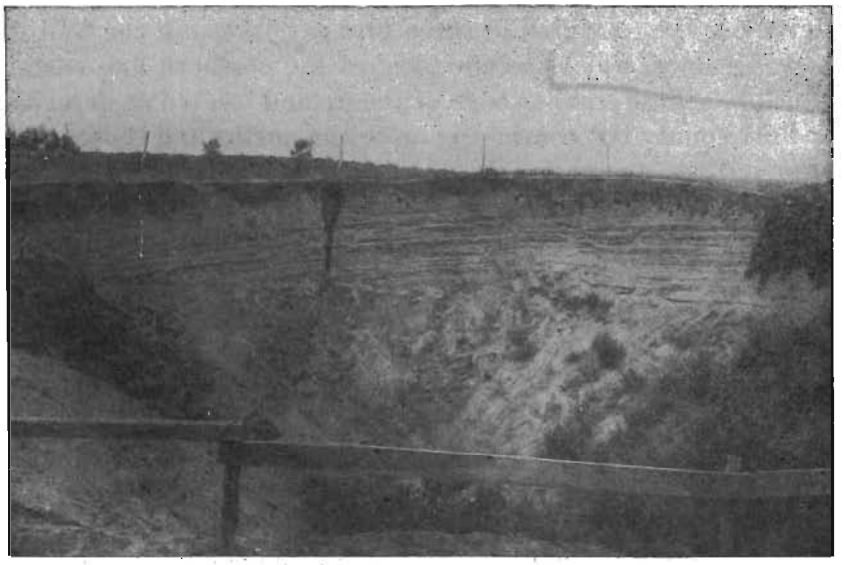


FIG. 10.—A gravel pit in a kame in the Algona moraine, Winnebago county.

morainic topography (see fig. 10), and most of the peat land is east of Lime creek. The Rice Lake, Turtle Lake and Bear Lake bogs are by far the largest and most important areas. One mile south of Lake Mills a brown fibrous sample, number 65, was dug; number 66, also brown and fibrous, was obtained four miles south of Lake Mills from the drained bed of Turtle Lake; and number 67, a good, dark brown to black peat, came from the bog half a mile east of Thompson. While these bogs attain maximum thicknesses of fifteen to thirty feet, each of the samples was made as a composite from the upper four feet of their respective sections.

Other important areas of peat are found north of the city of Lake Mills and also in the southeastern township of the county.

Worth County.—The Wisconsin till covers that part of Worth county lying west and north of a line passing approximately through Northwood, Hanlontown and Fertile. The bogs in the central and southern parts of this area are among the largest and best known in Iowa. Analyses 32 and 33 were made from brown but not well rotted material collected from two spots half a mile apart along the highway in the large bog northwest of

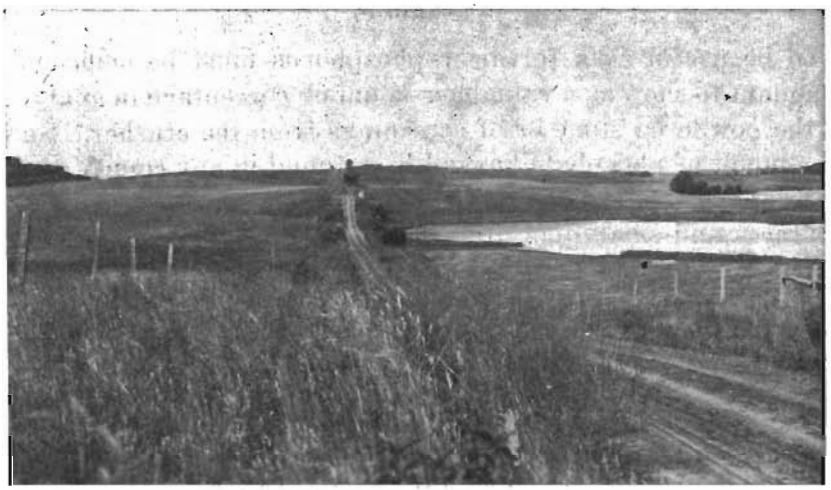


FIG. 11.—The Gary moraine near where the Humboldt moraines branch from it toward the southwest. Morse lake, four miles west of Belmond, Wright county.

the town of Fertile. This bog is situated just within the inner margin of the belt of hills forming the terminal moraine in this vicinity.

Wright County.—The peat land is found mostly in the eastern half of Wright county in and near the well defined morainic topography. The large bog one mile east of Wall lake is located in a depression between broad swells which mark stages in the recession of the margin of the glacial ice. Several bogs in the west-central and north-central parts of the county are in shallow basins in poorly defined recessional features and some of them are wholly within areas of clay soil.

Sample 64, a dark brown to black compacted peat, was ob-

tained from the large bog three miles west of Dows. This bog is located entirely among the rolling hills of the Gary moraine. Sample number 61 came from the bog six miles due north of Clarion, and is a fine brown nonfibrous peat. This bog is in a westward extension of the Gary moraine where it branches to form an alignment with the outer swells and low, flat hillocks of the Humboldt stages of the Wisconsin recession. (See fig. 11.) Each of the triangles on the map represents several small areas of peat.

Phosphate

To be useful as a fertilizer phosphorus must be sufficiently abundant to show as a valuable amount or percentage in analyses of the powdered stone or of screenings from the crusher. Such an amount of phosphate has not been found in any county in the state.

Traces and small quantities, however, were detected in many

FIG. 12.—The limestone quarry at Decorah in which small quantities of phosphate were found.

places. Most commonly phosphate occurs along the cracks (joint planes and bedding planes) in the rocks in which it has been found. Evidently it has been carried to these cracks by percolating water from rock at a higher elevation. Near Decorah, Peru and Keokuk phosphate was found to be present in limited quantities along joint planes, bedding planes and also in a few thin beds of limestone as is shown in the respective sections for these localities. (See fig. 12.)

Phosphate was found in limestone and dolomite as follows:

Ordovician (Galena)	— at Decorah
Devonian (Wapsipinicon)	— at Independence
Devonian (Cedar Valley)	— at Glory, Black Hawk county
Devonian (Cedar Valley)	— at Waverly
Mississippian (Osage)	— at Keokuk
Pennsylvanian (Des Moines)	— at Laddsdale, Wapello county
Pennsylvanian (Missouri)	— at Earlham and Peru.

In many quarries which were tested no trace of phosphorus was found.

Limestone and Dolomite

Methods of sampling.—Composite samples of limestone and dolomite were obtained for analysis from the respective quarries and outcrops by taking fragments from each bed or layer of fresh rock at equal vertical distances, commonly a few inches, throughout the height of the face.

Field tests.—Many tests were made with reagents in quarries from which no samples were taken for laboratory study. The reagents which were used in all quarries and on all outcrops tested were kept constantly on hand during the progress of the work and consisted of hydrochloric acid (about 8 per cent), concentrated nitric acid, and crystals of ammonium molybdate.

Limestone and dolomite.—Limestone is composed of calcium carbonate, $CaCO_3$, when pure, and dolomite contains both calcium carbonate and magnesium carbonate. In these tests the distinction between the two was made with dilute hydrochloric acid, about 8 per cent. The limestone effervesces or "bubbles" freely when a few drops of the acid are applied to a surface of fresh rock but the dolomite does not effervesce when so tested. Both

limestone and dolomite are soft and will not scratch the blade of a pocket knife but will be easily scratched by it. Sandstone, on the other hand, is composed of sand grains which scratch a knife blade easily.

Test for phosphate.—In the test for phosphates, a powdered crystal of ammonium molybdate was placed on a surface of the unweathered rock to be tested and a few drops of nitric acid were applied with a pipette to the powder. A yellow color appears in the powder if phosphate is present. If the color indicated more than a trace of phosphorus, a specimen was taken for use in making a percentage analysis in the laboratory.

Purity of rock.—Both limestone and dolomite when ground, crushed or pulverized are used in neutralizing the acid condition of the soil but the impurities do not aid in this work. Either is useful alone or a mixture of the two may be used after thorough grinding. The percentage of purity of a sample is found from its analysis given in the table by adding the percentage of calcium carbonate to that of the magnesium carbonate. In other words the purity of the rock considered as fertilizer is the total percentage of carbonates it contains. A rock having 70 to 80 per cent of carbonate can be successfully used but a smaller amount of rock will be necessary if it has a purity of 80 per cent or higher. The expense of freight and handling also decreases with the increase in purity of the rock.

Impurities.—While the amount of impurities present is commonly 5 to 10 per cent, it may run higher or lower in some tests. In most of the samples tested the impurity is largely silica, which is the chief substance in sand and in glass. The impurities also contain very small quantities of iron, aluminum and clay.

Chert.—Chert is composed of silica and is only an impure form of quartz. In nearly all of the larger groups of limestone beds in the state it occurs either as broad, flat, nodular lenses in the bedding planes between the layers of the rock or as lenses within the layers. Where chert is found between the layers of limestone, it may be thrown aside to prevent its passing through the crusher but where it is within the layers, this can not be done. It is very hard and breaks with shelly surfaces, forming sharp

edges. It is worthless as fertilizer material and is an abomination in the process of crushing the limestone, which is not more than half as hard as the chert. (See fig. 18.)

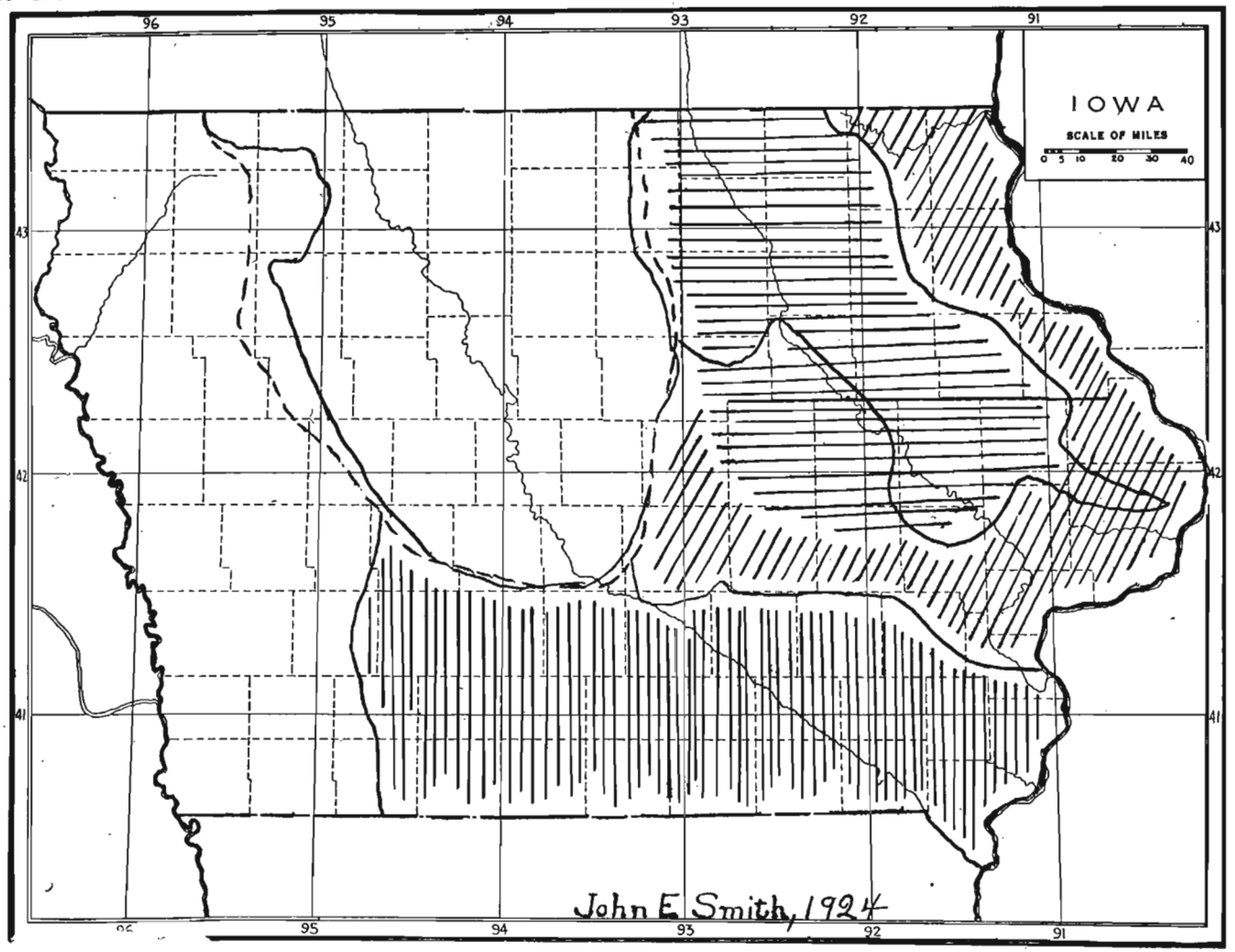
Chalk.—Chalk is a form or variety of limestone whose value as a fertilizer is, like that of other forms, determined by its location, abundance and purity. In some places it is soft and loose, in others it is harder and more firmly cemented. Chalk consists chiefly of the skeletal remains of very small forms of animal life. It is found in Iowa along the bluffs near Sioux City and northwestward where it occurs in layers ranging from a few inches to a few feet in thickness. Iowa chalk and its associated limestone are suitable for use wherever they are exposed in sufficient quantity to warrant the expense of installing a crushing plant.

USES OF AGRICULTURAL LIME.

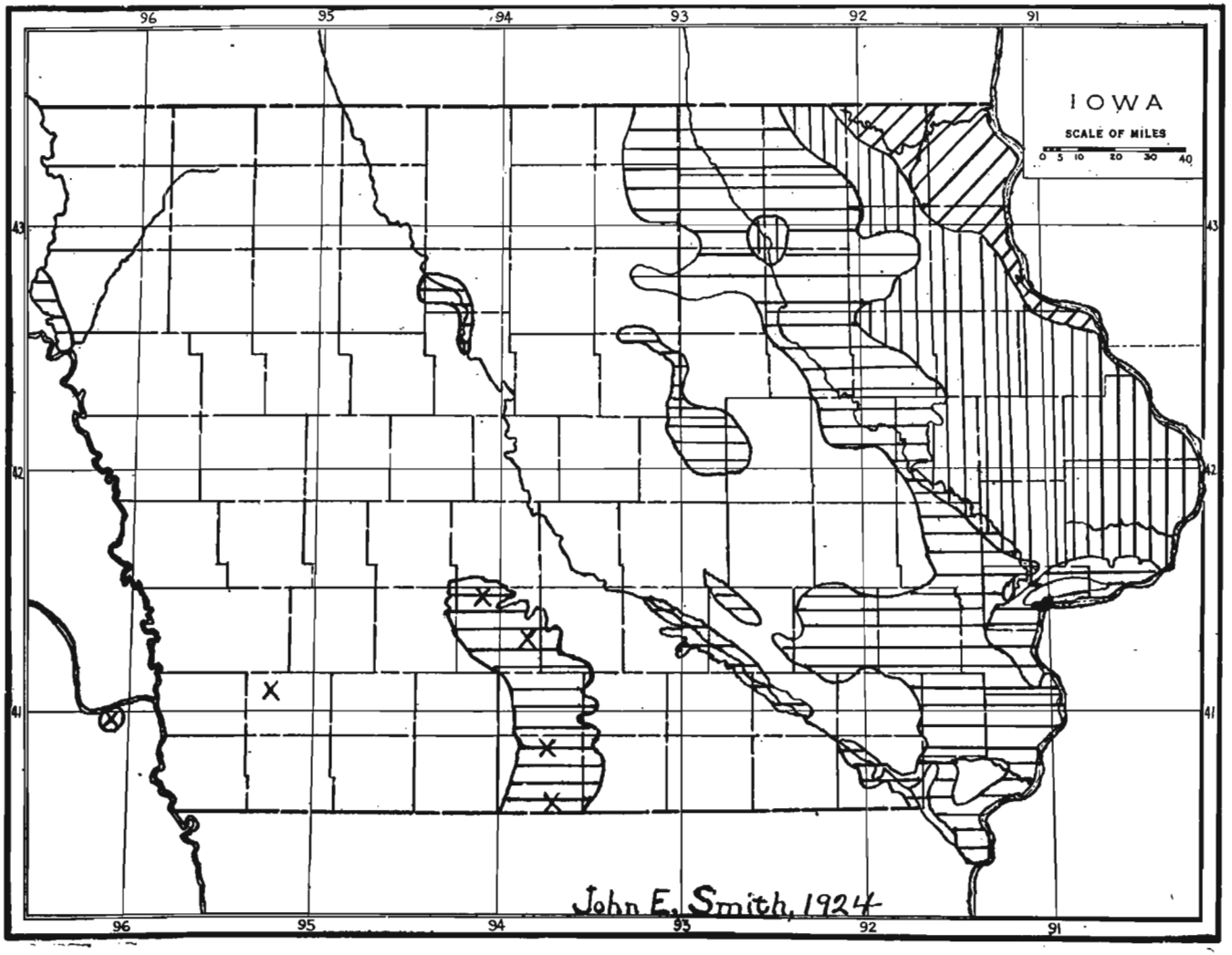
Lime is used in making cement, concrete, plaster, sheep dip, insecticides and sprays, also as a disinfectant in barns, chicken houses and elsewhere, in water purification and softening and in sewage purification. Limestone applied to soils corrects acidity, supplies available calcium for the use of plants, increases the effect of fertilizers and manures on soils, makes all plant food more available by aiding bacterial growth, assists in the control of certain plant diseases and insect pests, and as time goes on it improves the tilth of heavy soils and makes it possible to grow clover and alfalfa where none would grow without it.

About 10 to 15 per cent of the total output of lime in the United States is used as a soil amendment to neutralize "sour" or acid soil. For this purpose it is applied in two forms: first, as burned lime, also called quick lime before it is slaked and hydrated lime after slaking; and second, as raw, ground or pulverized limestone.

The hydrated or slaked lime is all very finely pulverized or powdered and its power to counteract the acid condition of the soil is largely exhausted during the first year after it is applied. The ground limestone on the other hand contains particles of many sizes, commonly less than three-eighths of an inch in diameter, and half of it or more should be ground to a fine powder. The finer particles are dissolved and used the first year



Map of Iowa showing approximate areas of relative need of lime on soils. The greatest need of lime is in the area shaded by horizontal lines; much lime is needed in the area shown by vertical lines; a smaller amount, in the area shown by diagonal lines, and some lime is needed in the unshaded areas. From many tests which have been made it is estimated that about 90 per cent of Iowa soils is in need of lime. A comparison of this map with Plate VI shows Iowa's limestone is where the lime is most needed.



Map to show by shading areas containing limestone and dolomite suitable for use as a fertilizer: horizontal lines show areas of limestone; vertical lines, areas of dolomite; diagonal lines, areas containing both limestone and dolomite. A thin layer of chalk is found in the area near Sioux City. X indicates limestone—if within circle, production of agricultural lime.

and some of the coarser remain in the soil to be dissolved and used later.

Lime from dolomite.—Some authorites consider that lime burned from dolomite is too caustic for repeated use on the same land. But no objection or very little is made to the use of raw, ground dolomite.

Need of agricultural lime in Iowa.—Hundreds of tests made by the Department of Soils, Iowa State College, show that nearly 90 per cent of the soils of the state need lime and that some parts of the state are much more in need of it than others. See Plates V and VI, pages 114 and 115. One part or another of nearly every county in the state needs lime on its soil.

The excellent and favorable location of Iowa limestone with respect to the areas in which crushed limestone is needed as a soil amendment is readily seen by comparing the shaded areas of Plate V with those of Plate VI. It will be observed that the area of Iowan glacial till, shown on Plate V by horizontal shading, is in greater need of the use of lime on its soils than most other parts of the state.

MARL.

This is most commonly a mixture of lime and clay very poorly cemented. The lime generally has its sources in shells, many fragments of which are irregularly distributed through the mass, which is commonly loose enough to be shoveled. To be useful as a fertilizer marl should contain 50 to 80 per cent of lime. Most Iowa marls are not sufficiently rich or abundant to be worth considering as fertilizer material where so much excellent limestone is available for crushing.

A shell marl that could be used locally for fertilizer is found in numerous places in Floyd and Cerro Gordo counties. These outcrops "can be traced with little interruption from the exposures west of the fair grounds in Cerro Gordo county to those several miles south of Rockford in Floyd county" (ref. 17, pp. 326-329). "The most important section exposed in the county (Cerro Gordo) may be viewed in section 35 in Portland township, facing a convex bend in Lime Creek and continuing a distance of about a mile." This place is known as the "Clay

Banks''. Three analyses of samples from here show that the marl contains 57.07 per cent, 57.42 per cent and 86.61 per cent of total carbonates respectively, though a sample taken just west of the Fair Grounds near Mason City runs as low as 36.78 per cent total carbonates. A hard, solid layer within the marl gave the test of 86.61 per cent mentioned above.

FIG. 13.—A view showing thin-bedded limestone above and thick-bedded limestone below.

The marl attains a thickness of twelve to twenty feet or possibly more and may be found also on the west side of Lime creek near Rockford just above the layers of clay that are used in brick and tile making. Numerous road cuts in both counties expose the marls near the hilltops west of Lime creek.

This layer of marl contains many of the most perfect fossils of shelled animals, one inch in diameter and smaller, that can be found in the state. Some benefit would result from the use of the marl without grinding but the shells in it are too coarse and should be crushed so that all of the lime in it may be available for it contains only a little more than half as much lime as is found in pure limestone. See also reference 67.

Analyses of Limestone in Northeastern Iowa

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
					Allamakee County					
Center	NE. ¼ 6	6	50	2 – 4	Good	8½mi	Yes	11.60	60.55	27.85
Jefferson	NE. ¼ 23	6	100	2	Good	1½mi	Near	5.11	93.33	1.56
Makee	NE. ¼ 31	12	100	1½– 2	Good	Yes	Yes	12.31	84.52	3.17
Ludlow	SE. ¼ 34	12	400	1½– 2	Good	7 mi	Yes	7.57	91.71	.72
Makee	NE. ¼ 30	10	150	3 – 6	Good	1 mi	Yes	8.29	90.51	1.20
Post	SW. ¼ 16	12	400	1½– 2	Good	3½mi	Yes	10.10	87.43	2.47
					Bremer County					
LaFayette	SE. ¼ 35	20	400	10 –15	Good	¾mi	Yes	5.88	80.56	13.56
LaFayette	SE. ¼ 35				Good	¾mi		10.28	80.33	9.39
					Buchanan County					
Perry	SE. ¼ 32	15	200	3½	Good	40 rd	Yes	4.45	91.80	3.75
Washington	SW. ¼ 35	15	300	1½– 2½	Good	40 rd	Yes	6.64	91.95	1.41
					Butler County					
Pittsford	NE. ¼ 23	10	400	2	Good	Yes	No	3.89	70.79	25.32
Shell Rock	SE. ¼ 11	8	75	2	Good	25 rd	Yes		96.11	
					Chickasaw County					
Bradford	SE. ¼ 20	10	200	½	Good	½mi	Yes	3.28	69.26	27.47
					Clayton County					
Boardman	NE. ¼ 23	16	150	2	Good	½mi	Yes	5.55	88.42	6.03
Farmersburg	S. ½ 18	6	150	1 – 3	Good	Yes	Yes	3.22	66.36	30.42
Garnavillo	NW.¼ 20	10	200	1 – 3	Good	7 mi	20rd	8.43	54.61	36.96
Cox Creek	NW.¼ 9	15	200	3 – 5	Good	20 rd	Yes	3.16	63.75	33.09
Giard	SE. ¼ 21	12	100	2	Good	Yes	20rd	5.03	54.88	40.09
Boardman	SW. ¼ 23	10	200	1 – 5	Good	Across river	Yes	17.49	78.50	4.01
Wagner	NW.¼ 25	10	100	1 – 3	Good	40 rd	Yes	7.14	68.36	24.50
					Fayette County					
Westfield	SE. ¼ 28	50	300	3 – 4	Good	Yes	Yes	4.92	89.99	5.09
Clermont	NE. ¼ 24	12	500	1 – 4	Good	3 mi	Yes	9.27	56.49	34.25
Clermont	NE. ¼ 34	15	100	1 – 3	Good	20 rd	Yes	14.60	67.72	19.68
Union	NE. ¼ 22	15	60	1 – 3	Good	Yes	40rd	4.28	85.81	9.91
Union	NW.¼ 17	12	150	1½	Good	40 rd	Yes	2.85	88.02	9.13
					Floyd County					
Rudd	NW.¼ 35	10	200	1 – 2	Good	3 mi	80rd	4.33	85.66	10.01
Floyd	SE. ¼ 16	20	200	2	Good	½mi	Yes	13.00	68.82	18.18
Floyd	SE. ¼ 16	Screenings						9.26	70.22	20.52
Riverton	NW.¼ 12	10	300	2	Good	2 mi	Yes	3.25	59.21	37.54
Rock Grove	NW.¼ 17	15	600	2 – 6	Good	80 rd	80rd	5.05	85.26	9.69
Union	NW.¼ 8	15	150	1 – 6	Good	80 rd	80rd	3.33	88.33	8.34

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Howard County						
Vernon Springs	SW. ¼ 22	10	300	2	Good	40 rd	Yes	14.98	52.38	22.64
Forest City	NW. ¼ 21	6	80	2	Good	1½ mi	Yes	11.43	85.31	3.26
Vernon Springs	SW. ¼ 22					40 rd	Yes	10.83	63.94	25.23
New Oregon	NW. ¼ 3	12	100	2 – 3	Good	3 mi	Yes	9.00	65.72	25.28
Chester	SE. ¼ 24	10	150	2 – 3	Fair	1 mi	Yes	19.10	48.62	32.28
				Mitchell County						
Osage	SW. ¼ 26	8	200	2 – 3	Good	1 mi	Yes	1.56	96.47	1.97
Osage	SE. ¼ 27	25	600	6 –20	Good	1½ mi	Yes	2.82	90.84	6.34
Newberg	NE. ¼ 22	35	800	4 – 6	Good	1½ mi	40rd	4.58	67.84	27.58
				Winneshiek County						
Calmar	E. ½ 20	6	150	2 – 3		2½ mi	Yes	36.64	62.16	1.20
Fremont	SE. ¼ 28	15	125	1	Good	8 mi	Yes	4.54	92.90	2.56
Washington	SW. ¼ 28	20	200	2	Good	4 mi	Yes	11.28	63.63	25.09
Decorah	S.W. ¼ 21	12	100	2	Good	40 rd	20rd	11.48	84.80	3.72
Highland	NW. ¼ 8	4	300	1	Good	4 mi	10rd	10.40	88.14	1.46
Bluffton	NW. ¼ 11	100	1000	3	Good	12 mi	Yes	8.19	86.90	5.91
Sumner	SE. ¼ 18	10	100	2 – 3	Good	8 mi	Yes	10.39	85.36	4.25
Washington	Center 7	30	150	0	Fair	¼ mi	Yes	21.15	54.73	24.12
Madison	SW. ¼ 23	roadside	cut		Good	3 mi	Yes	39.30	61.91	22.61
Pleasant	SW. ¼ 26	40	1000	0	Good	11 mi	Yes	8.68	58.45	32.87
Decorah	NE. ¼ 5	10	200	2½	Good	4 mi	Yes	7.10	90.99	1.91
Hesper	NW. ¼ 14	7	60	2	Good	5 mi	Yes	7.25	89.62	3.13
Decorah	SE. ¼ 9	20	300	1	Good	1 mi	Yes	8.06	88.37	3.57
Highland	SE. ¼ 23	30	1000	6	Fair	11 mi	Yes	16.56	46.07	36.37
Bluffton	Center 17	12	120	1	Good	8 mi	Yes	14.80	66.46	18.74
Jackson	E. ½ 1	8	100	2 – 3	Good	2 mi	Yes	3.80	56.81	39.39
Frankville	N. ½ 23	12	200	2	Fair	7 mi		22.52	67.32	10.16
Frankville	N. ½ 10	20	150	3		10 mi		8.06	89.66	2.28

The total carbonates in any analysis in these tables are found by adding the calcium carbonates and the magnesium carbonates. This sum will give the percentage of purity of the rock as a fertilizer material.

All analyses given in the tables on pages 118, 126, 128, 138 and 142 were made by Horace J. Harper as were the analyses of screenings and stone dust from localities referred to in these tables.[1]

It will be noticed that the screenings and ground limestone are lower in percentage of total carbonate than the analyses from the face rock. This is due partly to the admixture of dirt during

[1] These data are used by permission of Dr. W. H. Stevenson and Dr. P. E. Brown, heads of the Department of Soils, Iowa State College, and of Professor Harper of the same department.

the process of crushing and handling but chiefly to the fact that the composite specimens and samples were all chipped from the solid rock while the material put through the crusher includes very thin layers of clay which are present in nearly all quarries along the cracks in the rocks—namely the joints and the bedding planes.

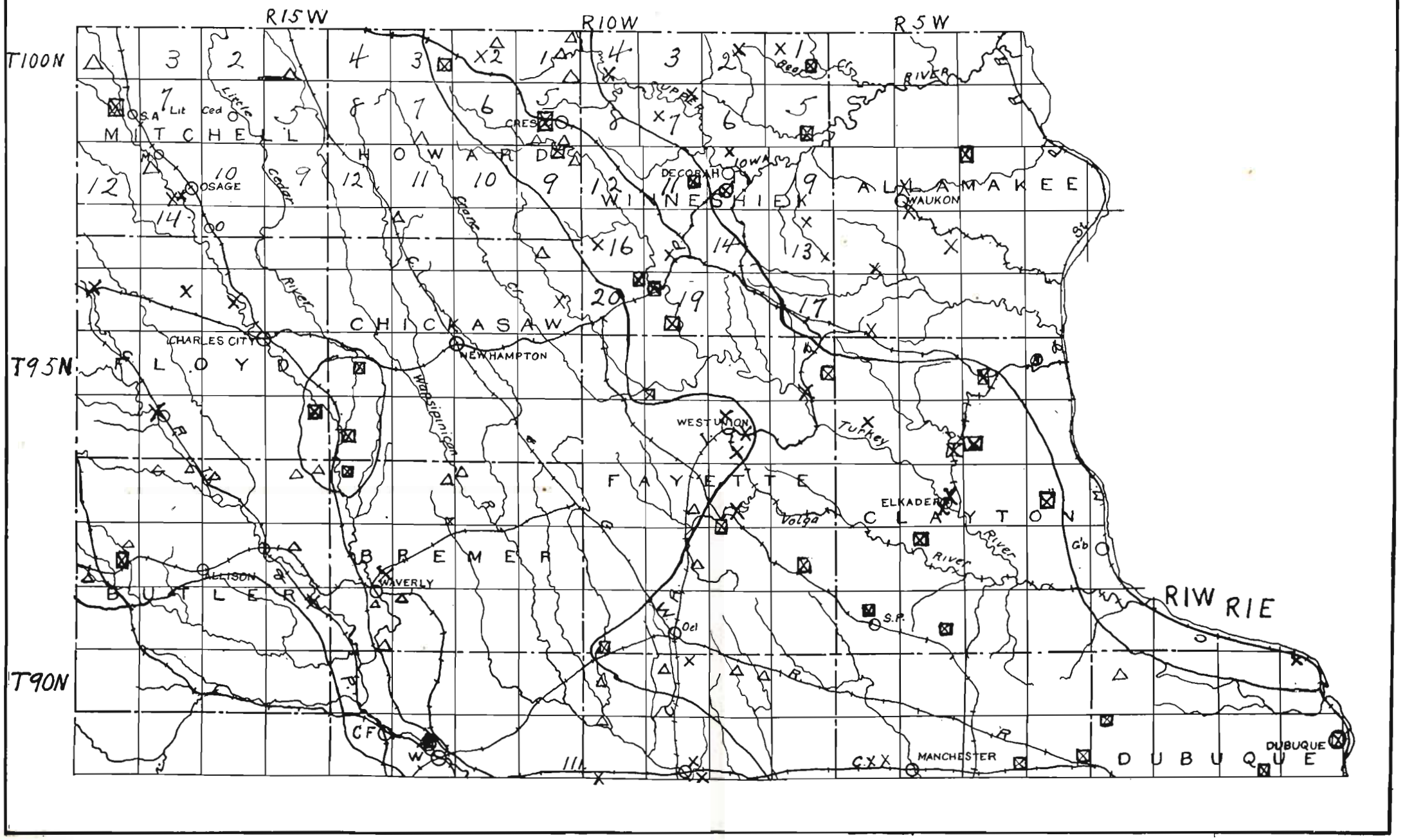
NORTHEASTERN COUNTIES.

The locations of many of the important outcrops and quarries in the great limestone region of eastern Iowa are shown on the maps of Plates VII, VIII and IX. These maps near pages 120, 130 and 140 respectively give details of the areas mapped on Plate VI including locations of the several details within their respective townships.

Allamakee County.—The analyses given in the table, page 118, show only one specimen of dolomite from Allamakee county, that from Center township, township 98 north, range 4 west, and this sample contains a total of 88.4 per cent of carbonates. It is therefore, a good grade for use as fertilizer. The analyses give 11.6 per cent of impurity in a sample from Post township in the southwestern corner of the county and 87.69 per cent of carbonates for the specimen from Makee township, number 98 north, range 5 west.

Jefferson is township 97 north, range 5 west and Ludlow is 97 north, range 6 west. In these and in Makee township, section 30, the total carbonates range between 91 and 95 per cent.

Bremer County.—The outcrops of limestone in Bremer county are practically all in the western end of the county and consist of limestone and magnesian limestone. In the southeast quarter of the southwest quarter of section 20 in township 91 north, range 13 west, in a ravine tributary to Quarter Section Run, is found limestone containing 96.57 per cent of calcium carbonate and 1.80 per cent of magnesium carbonate (ref. 44, p. 351). In section 8 of Polk township, three miles north of Plainfield, dolomite of the following composition is found: residue, 5.40 per cent; calcium carbonate, 55.23 per cent; magnesium carbonate, 39.03 per cent; total carbonates, 94.36 per cent (ref. 44, p. 358). Some analyses from Waverly (Devonian) (ref. 66, p. 531) show the following composition: insoluble, 2.25 and 7.74 per cent;



MAP OF NORTHEASTERN IOWA. X SHOWS LOCATION OF QUARRY OR OUTCROP OF LIMESTONE; X WITHIN A SQUARE, QUARRY OR OUTCROP OF DOLOMITE. A CIRCLE AROUND EITHER INDICATES PRODUCTION OF AGRICULTURAL LIME. OTHER QUARRIES AND OUTCROPS ARE INDICATED BY TRIANGLES. SOLID LINES INDICATE APPROXIMATE BOUNDARIES OF AREAS SHOWN IN PLATE VI.

iron and alumina, 1.32 and 1.67 per cent; calcium carbonate, 88.65 and 86.80 per cent; magnesium carbonate, 6.70 and 2.35 per cent. Tests for phosphate from the John Carey quarry in the south half of section 11, Washington township, give 1.74 per cent of P_2O_5. (Analysis by H. E. Flanders.)

Screenings from the ground material whose analysis is given in the table on page 26 tested as follows: impurities, 10.28 per cent; calcium carbonate, 80.33 per cent; magnesium carbonate, 9.39 per cent; total carbonate, 89.72 per cent.

Buchanan County.—North and east of a line drawn through Fairbank, Bryantburg and Winthrop and passing southeastward just west of Buffalo creek, the rock of Buchanan county is chiefly dolomite. A notable exception to this dolomite is found in the southwest quarter of the southeast quarter of section 2, Hazelton township, township 90 north, range 9 west, at the old lime kiln, where the rock is a good grade of limestone. The beds of limestone in the remaining western and southwestern parts of the county consist of rock containing about 90 per cent or more of calcium carbonate. (See ref. 23.)

The analysis given in table, page 118, for Washington township was made from a sample taken from the old city quarry at Independence. The results of field work seemed to show that this quarry had a uniform distribution of phosphate so tests for P were made and these yielded the following percentages of phosphate: 0.74, 0.78 and 0.74 respectively. (Analyses by H. E. Flanders.)

Butler County.—The bed rock in the eastern part of Butler county is nearly all a good grade of limestone. One sample which was analyzed was taken from a quarry about one and one-half miles west of Bristow in Pittsford township, which is township 92 north, range 18 west. This sample is strongly dolomitic. The outcrops around Dumont, however (see ref. 2), consist of a good grade of limestone. The analyzed sample from Shell Rock was procured in the northeast part of the city. For composition see table, page 118. The total carbonates in each of these samples exceed 96 per cent.

Chickasaw County.—More than half of the townships of Chickasaw county have no outcrops of bed rock. In the eastern part

there are a few rather poor exposures of limestone along Crane creek and Turkey river. (See map, page 120.) In the western one-fourth of the county dolomite and highly magnesian limestone are found along Cedar river and one mile south of Nashua. These outcrops represent an abundance of rock which showed the following percentage composition: $CaCO_3$, 69.26; $MgCO_3$, 27.47; impurities, 3.28; total carbonates, 96.76.

The other specimen was collected from the outcrop along the railroad near the cemetery two miles south of Nashua. Here the test shows: 7.19 per cent of impurities, mostly silica; $CaCO_3$, 75.35 per cent; $MgCO_3$, 16.95 per cent; P_2O_5, 0.16 per cent; total carbonates, 91.80 per cent. (Analysis by E. H. Wallace.)

Clayton County.—Most of the outcrops south of Volga and the Turkey rivers, especially those high on the bluffs, are ledges of dolomite whose thickness aggregates 100 to 200 feet and which extend westward into Fayette and southward into Delaware and Buchanan counties. In the eastern and northern parts of the county the beds of limestone, shale and dolomite alternate much the same as is shown in the following section:

Section at Guttenberg
(Trenton-Galena)

		Feet
1.	Limestone, dolomitic, in heavy ledges, vesicular, coarse and buff-colored	100
2.	Limestone, magnesian, in beds two inches to a foot thick, fine-grained, compact and gray to coarse, rough and buff, some chert bands and nodules, partly changed to dolomite containing 16 per cent magnesium carbonate. Supplied limestone to the old kilns at the base of bluff	60
3.	Limestone, nonmagnesian, fine-grained, compact, gray, in thin uneven beds, lower part covered on slope	85
4.	Limestone, dolomitic, blue weathering to buff, beds eight inches to two feet thick. Exposed in the quarries	15
5.	Sandstone (St. Peter), covered, to water level in river	10

Farther northwest and north, limestone about ninety feet thick underlies this sandstone, and forms a considerable part of the steep bluffs along the deeper creek valleys and river valleys.

"All the evidence bearing on the subject points to the conclusion that the Galena dolomite is derived from non-dolomitic limestone by alteration which has taken place subsequent to the deposition of the strata." "Occasionally the change appears to take place first along the bedding planes and joints. A bed two inches thick was observed which had been partially altered to

magnesian limestone on the upper and lower surfaces while the inner portion was unaffected. In other cases the alteration had commenced in that portion of the rock immediately surrounding the fossils, an orthoceros, for example, being encircled with a ring of magnesian limestone." "In the limestone portions of the rock the fossils are well preserved, but in the dolomitized parts they have been obliterated."

The samples analyzed were taken from two quarries near Elkader, from outcrops located respectively half a mile south of Farmersburg, two miles west of Garnavillo, one and one-half miles northeast of Osborne, one-fourth of a mile west of Beulah, and one-fourth of a mile north of St. Olaf.

Fayette County.—The outcrops in the western half of Fayette county consist chiefly of impure limestone but those in the eastern and northeastern parts are mostly dolomite or dolomitic limestone. The quarries about West Union and Fayette contain limestone testing 85 to 90 per cent of calcium carbonate and 5 to 10 per cent of magnesium carbonate. (See map, page 120.)

Other analyses for the county are given in reference 66, page 533, as follows. From the Maquoketa formation at Clermont: insoluble residue, 11.95 per cent; iron and aluminum, 2.80 per cent; calcium carbonate, 84.80 per cent; magnesium carbonate, 0.45 per cent. Dolomite from Williams' quarry six miles south of Postville in the Hopkinton formation: insoluble, 8.65, 8.50, 9.00, 10.64 and 9.52 per cent; iron and alumina, 0.66, 5.37, 3.00, 1.06 and 3.10 per cent; calcium carbonate, 58.13, 41.16, 52.12, 50.03 and 52.14 per cent; magnesium carbonate, 32.18, 45.18, 36.05, 38.50 and 35.72 per cent. At Auburn, in the Hopkinton formation, a limestone contains 98.52 per cent of calcium carbonate. The total carbonates at the Williams' quarry by analyses are 90.35 per cent, 86.34 per cent, 88.17 per cent, 88.53 per cent, and 87.86 per cent respectively.

Floyd County.—In Riverton township, 94 north, range 15 west, and all along Cedar river dolomite and highly magnesian limestone are common. In Rock Grove township, 96 north, range 18 west, near Nora Springs, and in Union township, 94 north, range 17 west, near Marble Rock, and also along Shell Rock river generally through the county the limestone is more nearly pure. At the concrete bridge northeast of Floyd station in

township 96 north, range 16 west, alternating beds of limestone and dolomite one to three feet thick are found in the quarries. The composition of these beds is shown in the analyses by E. H. Wallace given below:

	Impurities, per cent	$CaCO_3$, per cent	$MgCO_3$, per cent	Total carb., per cent
No. 28. Dolomite	16.41	51.77	31.57	83.34
No. 29. Limestone	1.88	90.30	7.45	97.75

The deficiency in the composition of the dolomite is due to the presence of clay as an impurity. The screenings from the crushed rock from Floyd township whose analysis is given in the table on page 118 tested as follows: impurities, 9.26 per cent; calcium carbonate, 70.22 per cent, magnesium carbonate, 20.52 per cent; total carbonates, 90.74 per cent. For marl in Floyd county see page 116.

Howard County.—In the northern part of Howard county along Upper Iowa river and Beaver creek, the rock is mostly dolomite and this is true also of the outcrops in the southwestern part of the county around Elma. In the east-central part of the county some of the beds are more highly magnesian than others. The rock in the quarries near Cresco also is a magnesian limestone. Forest City township is 100 north, range 12 west, and Chester is in range 13 west. New Oregon is township 98 north and Vernon Springs is 99 in range 11 west. Township 98 north, range 13 west is known as Howard township.

Screenings from the city quarry in Vernon Springs township, SW. ¼ of sec. 22 (see table page 119), have the following composition: impurities, 10.83 per cent; calcium carbonate, 63.94 per cent; magnesium carbonate, 25.23 per cent; total carbonates, 89.15 per cent.

Mitchell County.—Recent analyses of limestones of Mitchell county will be found on page 119. Most of the outcrops in the northwestern part of the county consist of much dolomite and highly magnesian limestone. Professor Calvin says (ref. 28), speaking of the quarry at McIntire, "Any given bed may be unaltered limestone in one place and granular dolomite in another."

Reference 66, page 535, gives three analyses of "Cedar Valley" limestone at Osage showing a purity of 98.01 per cent, 90.17 per cent and 98.01 per cent respectively.

New Burg township is 99 north, range 18 west. Osage is in the township of the same name, Cedar is an irregular township southwest of Osage and Otranto is in the northwest corner of the county.

Winneshiek County.—The analyses show that nearly all of the outcrops in Winneshiek county that have been tested consist of limestone rather than dolomite, though some of the areas contain a slightly magnesian variety.

Township 100 north, range 7 west is Highland; the same number in range 8 is Hesper and that in range 10 is Fremont. In township 99, range 7 west is Pleasant and 9 west is Bluffton. In township 98 north, Decorah is in range 8 and Madison is in range 9. In township 97 north, Frankville is in range 7 west, Calmar in 9, and Sumner in range 10 west. Washington township, 96 north, is in range 9 west, and Jackson is 96 north, range 10 west.

Three analyses taken from reference 66, page 537, of limestone from the Galena formation at Decorah, show respectively: insoluble residue, 14.53, 3.86 and 6.87 per cent; Fe and Al, 6.49, 2.54 and 1.00 per cent; $CaCO_3$, 72.89, 91.19 and 88.97 per cent; $MgCO_3$, 1.03, .84 and 2.86 per cent; total carbonates, 73.92, 92.03 and 91.86 per cent.

There are a number of outcrops of limestone in the county whose exact locations are unknown to the writer.

Section at Decorah

(One mile south of Court House, near stock yards)

		Feet
1.	Stripping or overburden	5 to 8
2.	Limestone, gray to buff, chert nodules larger above, small intraformational conglomerate near middle; gave weak reaction for phosphate	12
3.	Limestone, gray to buff, with bands of blue phosphatic limestone 4 to 12 inches wide	15
4.	Limestone, gray, a few narrow bluish phosphatic streaks	12
5.	Limestone, bluish, thin-bedded, weak reactions for phosphate along bedding planes and joints	2
6.	Limestone, shaly, contains much clay	⅛ to ½
7.	Limestone, blue-gray to buff, thick-bedded, some chert nodules; weak reactions for phosphate along the cracks	6

Analyses from above section
(by *E. H. Wallace*)

	Impurities, per cent	$CaCO_3$, per cent	$MgCO_3$, per cent	P_2O_5, per cent	Total Carbonates, per cent
Screenings from crusher	12.40	85.05	2.05	0.34	87.10
Composite from face rock	12.25	83.00	4.45	0.415	87.45
Select specimen from face rock	14.55	83.10	1.68	0.386	84.78
Phosphatic band in No. 3	10.02	83.50	4.61	1.83	88.11

In the southwest quarter of section 23, Madison township, the partly decayed limestone taken from a roadside cut was found to be composed of 61.19 per cent of calcium carbonate and 22.61 per cent of magnesium carbonate; total, 83.8 per cent (ref. 34).

Analyses of Limestone in North-central Iowa

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Cerro Gordo County						
Lime Creek	S. ½ 34	25	2000	3	Good	Yes	Yes	1.33	97.70	1.17
Lime Creek	S. ½ 34	25	2000	3				3.39	95.23	1.38
Lime Creek	NW.¼ 27	20	600	3	Good	Yes	Yes	1.98	89.24	8.68
				Franklin County						
Mott	NW.¼ 28	15	100	2½	Good	Yes	60rd	6.24	69.22	24.54
Ingham	NE. ¼ 28	6	100	4 – 6	Good	Yes	20rd	8.23	85.04	6.73
				Hamilton County						
Independence	SW. ¼ 17	6	50	3	Good	4 mi	20rd	9.75	86.24	4.01
				Hardin County						
				1 –10						
Hardin	NE. ¼ 19	20	400	sandstone	Good	20rd	20rd	1.10	88.20	10.70
Alden	NE. ¼ 18	30	600	2 – 3	Good	Yes	Yes	.84	87.87	11.29
Alden	NE. ¼ 18	(Scrgs from Hale Roberts)				(muddy at times)		18.88	78.97	2.15
				Humboldt County						
Rutland	SE. ¼ 35	6	200	2 – 6	Good	1 mi	40rd	4.98	87.27	8.78
Corinth	NW.¼ 3	12	60	1 – 6	Good	1½mi	20rd	1.02	95.84	3.14
				Pocahontas County						
Garfield	SW. ¼ 25	20	900	2 – 4	Good	Yes	Yes	.75	88.81	10.44
Same location								3.13	93.80	3.07
				Webster County						
Cooper	SE. ¼ 17	6	70	6 –14		20rd	Yes	3.98	76.83	19.19

NORTH-CENTRAL COUNTIES.

Cerro Gordo County.—Several analyses of samples from this county have been made, see table on page 126, and these show a composition ranging from 95 to 98 per cent of total carbonates. Reference 66, page 532, gives two analyses of limestone from "Mason City" which contain 95.54 per cent and 98.47 per cent of carbonates respectively. A sample of the screenings at Northwestern Portland Cement Company's plant tested 96.61 per cent of carbonates. This high degree of purity is a characteristic of the limestones of the county.

An analysis by E. H. Wallace of a sample collected in the southeast quarter of section 19, Union township, about four miles east of Manly, on Shell Rock river, shows the composition of the rock to be P_2O_5, 0.22 per cent; $CaCO_3$, 74.30 per cent; $MgCO_3$, 23.30 per cent; total carbonates, 97.60 per cent. Concerning marl in Cerro Gordo county see page 116.

Franklin County.—The specimen of magnesian limestone which was analyzed (see table, page 126) came from the old quarry along the creek in the northwest quarter of section 28, Mott township, about two miles north of Hampton, and is 93.74 per cent pure. The northeast quarter of section 28, Ingham township, is about seven miles east of Hampton, near Hansell. The limestone here contains 91.77 per cent of total carbonates.

Hamilton County.—The sample of limestone from Hamilton county whose analysis is given on page 126 was taken from a thin bed in an outcrop on Boone river. Though the rock is good in quality it is not sufficiently abundant to make its exploitation a profitable enterprise.

Hardin County.—The northeast quarter of section 19, Hardin township, is at Iowa Falls, where the slightly magnesian limestone tested 98.9 per cent of carbonates. The samples from Alden township were taken at Alden (Hale Roberts quarry). The second test made on screenings from here runs lower in purity because of the mud and dust which sometimes are permitted to become mixed with the screenings. This reduction of about ten per cent in purity can be avoided by care in handling the material. See analyses, page 126.

Humboldt and Pocahontas Counties.—As shown in the tables,

page 126, giving composition of limestones in Humboldt and Pocahontas counties, the maximum percentage of carbonates reaches 98.98 in one analysis and 99.25 in another. This area includes the producing localities around Gilmore City, the district near Rutland and the outcrops at Humboldt and southward along Des Moines river. The second analysis given in the table under Pocahontas county is for screenings at the cement plant, Gilmore City.

Analyses found in reference 66, page 533, give the following: "Humboldt", 97.98 per cent and 99.20 per cent of carbonates; and "near Gilmore City", 99.62 per cent total carbonates.

These percentages are among the very highest ascertained by test in the entire state.

Webster County.—The limestone of Webster county is of the same age (Mississippian) geologically considered, as that along Des Moines and Skunk rivers in southeastern Iowa and occurs in the bed and on the banks of Lizard creek and of Des Moines river near Fort Dodge and northward to the county line. The quality of this rock is excellent but its upper part is too near the level of the water table for it to successfully compete with the equally high grade limestone from Rutland and Gilmore City.

Analyses of Limestone in East-central Iowa

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Benton County						
Jackson	SE. ¼ 28	20	400	3 – 4	Good	Yes	No	3.62	87.67	8.71
Taylor	S. ½ 10	20	300	3 – 4	Good	1½mi	Yes	9.97	89.32	.71
Harrison	NW.¼ 9	25	400	2 – 3		3¼mi	40rd			
				Black Hawk County						
Spring Creek	NW.¼ 36	25	600	4	Good	Yes	Yes	11.65	72.81	15.54
Spring Creek	NW.¼ 36	25	600	4	Good	Yes	Yes	11.27	80.32	8.41
Spring Creek	N.W.¼ 36	screenings			Good	Yes	Yes	13.57	69.94	16.49
Cedar Falls	NE. ¼ 23	7	150	3 – 4	Good	Yes	Yes	4.13	80.63	15.24
E. Waterloo	NW.¼ 14	30	600	3 – 6	Good	Yes	Yes	19.14	59.61	21.25
				Cedar County						
Gower	NE. ¼ 19	40	800	4 – 6	Good	Yes	Yes	3.22	57.35	39.43
Sugar Creek	SW. ¼ 15	20	300	4 – 5	Good	5 mi	Yes	2.10	55.24	42.66

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Clinton County						
Waterford	SE. ¼ 27	12	100	2 – 4	Good	Yes	Yes	4.28	54.14	41.58
City of Clinton	NW.¼ 12	25	300	6 –20	Good	80rd	Yes	1.94	59.44	39.62
				Delaware County						
Elk	SW. ¼ 16	15	300	2	Good	2½ mi	Yes	9.78	50.70	39.52
Delaware	35	10	200	2	Good	½ mi	20rd	1.85	54.21	43.94
Bremen	NW.¼ 25	7	250	1	Good	160rd	20rd	1.06	57.73	41.21
Oneida	NE. ¼ 36	8	200	2	Good	Yes		1.54	56.91	41.55
Delhi	NE. ¼ 19	6	150	2	Good	80rd	20rd	7.99	54.39	37.62
Delaware	NE. ¼ 2	8	200	2 – 3	Good	160rd	Yes	4.25	63.48	32.27
				Dubuque County						
Vernon	NE. ¼ 10	25	500	2 – 6	cherty	Yes	Yes	3.61	52.82	43.57
Taylor	NW.¼ 11	14	100	1 – 2	Good	20rd		4.10	53.78	42.12
"N. Dubque"	SE. ¼ 7	screenings 25	600	2 – 3	Good	Yes	Yes	10.54	46.14	43.32
Taylor	SE. ¼ 6	30	400	3	cherty	Yes	Yes	7.53	52.60	39.87
				Jackson County						
South Fork	NW.¼ 23	40	600	2 – 4	Good	1 mi	Yes	1.90	56.32	41.78
South Fork	W. ½ 12	30	500	2 – 4	Good	Yes	Yes	3.50	57.82	38.68
Bellevue	SE. ¼ 12	20	300	2 – 5	Good	40rd	Yes			
				Johnson County						
Jefferson	NW.¼ 22	15	200	4 – 6	Good	80rd	Yes	3.94	94.18	1.88
East Lucas	SE. ¼ 3	30	300	2 – 6	Good	1 mi	Yes	4.52	94.47	1.01
Big Grove	23							5.47	93.11	1.42
				Jones County						
Fairview	NE. ¼ 6	50	600	3 – 8	Good	Yes	Yes	3.13	56.06	40.81
Fairview	SW. ¼ 5	40	600	3 – 8	Good	Yes	Yes	4.59	54.72	40.69
Fairview	SW. ¼ 5	Screenings			Good	Yes	Yes	5.88	52.86	41.26
Cass	SW. ¼ 33	60	800	4 – 6	Good	Yes	Yes	5.81	53.28	39.91
Cass	SW. ¼ 33	Screenings			Good	Yes	Yes	3.79	58.09	38.12
				Linn County						
Franklin	NE. ¼ 15	20	200	3 – 5	Good	40rd	Yes	2.06	58.03	39.91
Franklin	NE. ¼ 15	Screenings			Good	40rd	Yes	3.41	59.45	37.13
"Cedar Rapids"	NE. ¼ 27	25	200	4 – 6	shaly	Yes	20rd	24.64	65.39	9.97
Buffalo	NW.¼ 20	20	200	3 – 5	Good	6 mi	Yes	Total	94.34	
				Marshall County						
LeGrand	SW. ¼ 3	30	300	2 – 5	Some chert 6 cherty layers	Yes	Yes	2,73	80.69	16.58
LeGrand	W. ½ 3	40	1000	10 –30		Yes	Yes	3.57	74.09	22.34
Marion	S. ½ 36	10	200	4 – 6	Good	Across river	Yes			

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Scott County						
Davenport	NW.¼ 33	20	200	2 – 4	Shaly	Yes	Yes	12.88	85.42	1.70
Davenport	NW.¼ 33	20	200	2 – 4	Shaly	Yes	Yes	12.22	85.14	2.64
Buffalo	SW. ¼ 21	25	1000	3 – 5	Shaly	Yes	Yes	21.09	75.14	3.77
Buffalo	SW. ¼ 21	25	1000	3 – 5	Shaly	Yes	Yes	14.43	83.36	2.21
Buffalo	SW. ¼ 21	25	1000	3 – 5	Shaly	Yes	Yes	12.74	82.48	4.78
LeClaire	W. ½ 26	10	200	4 – 5		Yes	Yes	5.30	61.41	33.25
Buffalo	NW.¼ 24	30	600	3 – 4	Shaly	Yes	Yes	15.79	77.10	7.11
Buffalo	NW.¼ 24	30	600					15.57	76.12	8.31
				Tama County						
Indian Village	SE. ¼ 7	10	150	2 – 5	Good	1 mi	Yes		84.50	

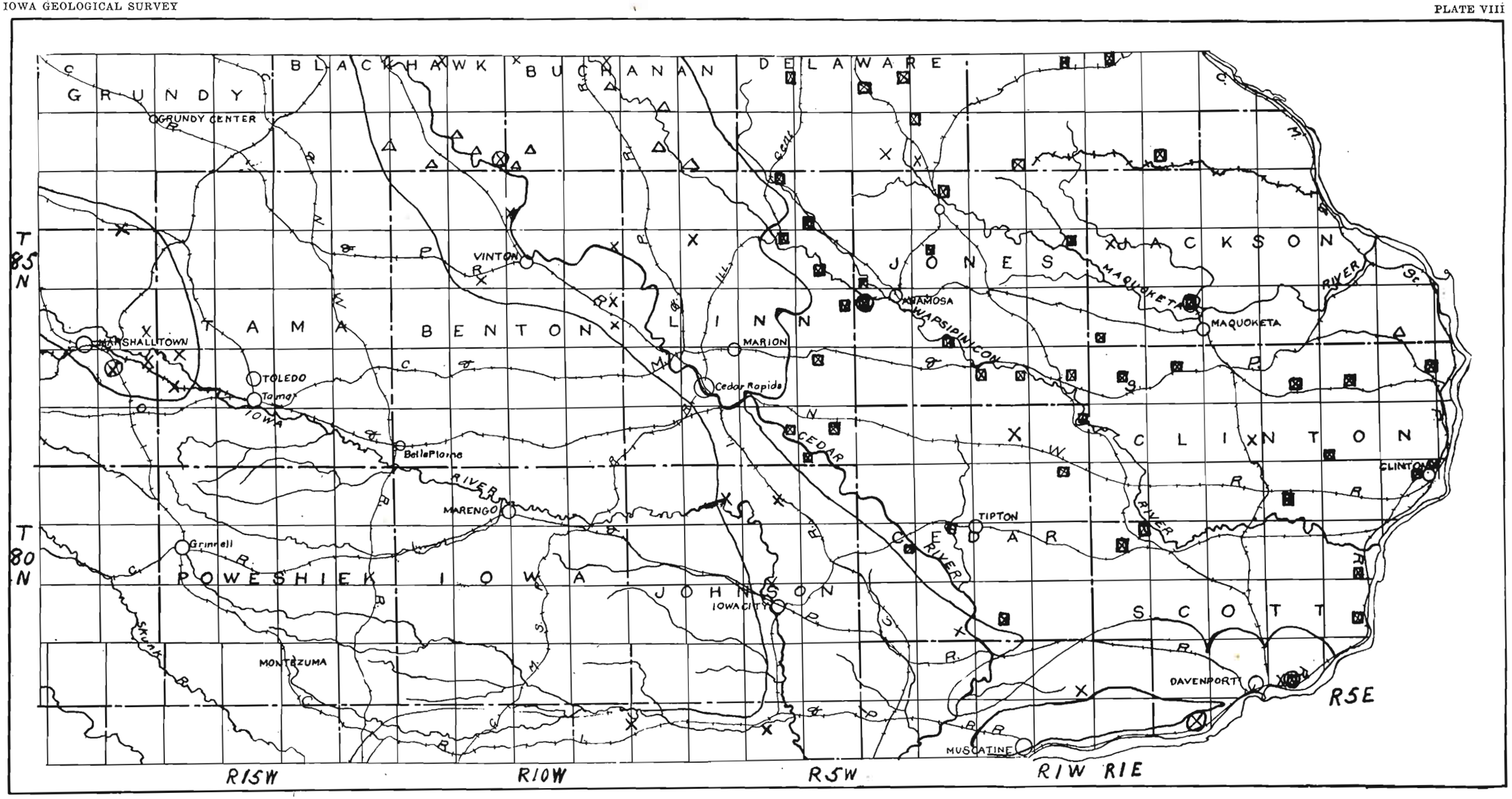
EAST-CENTRAL COUNTIES.

Benton County.—On the eastern margin of the city of Vinton there are several outcrops of good limestone some of which have been quarried to a small extent. The limestone in the old quarries near Shellsburg was carefully tested and, like that in the quarries at Vinton, was found to be well adapted to use as fertilizer though phosphate is absent in each of these localities. Limestone of good quality is found near Garrison also. North of Vinton on the Aungst farm and still further north on the same (west) side of Cedar river, quarries of high grade limestone were found to contain slight traces of phosphate. Several outcrops of high grade limestone are found east of Cedar river.

The principal outcrops of limestone in Benton county are shown on the map opposite page 130 and indicated in the table on page 128. Norton (ref. 47A, p. 374) also gives a number of analyses for Linn and Benton counties showing that the total carbonates range from 92 per cent to 96 per cent.

Black Hawk County.—Practically all of the limestone outcrops in Black Hawk county consist of magnesian limestone ranging in purity from about 80 per cent in the eastern and southern parts to 90 per cent of calcium carbonate in the region around Cedar Falls.

Reference 66, page 531, gives an analysis of a sample of lime-



EAST CENTRAL COUNTIES. X INDICATES LIMESTONE; X IN SQUARE, DOLOMITE; TRIANGLE, MINOR OUTCROPS AND QUARRIES. EITHER WITHIN A CIRCLE INDICATES PRODUCTION OF AGRICULTURAL LIME. A BLACK LINE SHOWS APPROXIMATE BORDERS OF THE AREAS OF PLATE VI.

stone (Cedar Valley) from Waterloo with percentages as follows: insoluble, 1.92; iron and alumina, 4.20; calcium carbonate, 63.59; and magnesium carbonate, 30.92; total carbonates, 94.51.

The succession of beds in the southeastern township of the county is well represented at the quarries of Hawkeye Quarry Company at Glory between LaPorte City and Brandon on the Interurban railway.

Section at Glory, Iowa
(Cedar Valley)

		Feet
1.	Limestone, weathered, brown to yellow, thick to thin-bedded	10
2.	Shale, clay parting, very thin	
3.	Limestone, buff to gray, lithographic in upper part; gives weak reaction for phosphate	5
4.	Shale, clay parting, maximum thickness about one inch	
5.	Limestone, blue, thin chert nodules and lenses, thin shaly partings present; tests for phosphate in cracks	10
6.	Limestone, buff, granular, very slightly phosphatic	1
7.	Limestone, blue, thick-bedded, two bands of buff color 4 feet apart; some slightly phosphatic nodules	10

Cedar County.—Cedar county, like Linn, has two areas of lime rock, the dolomite east and north of the line shown on the map along Cedar river and the limestone west of it. The position of the dividing line is only approximately correct as shown on the map and continues in a southeasterly direction across the northeastern corner of Johnson county. Analyses of the limestone show percentages of $CaCO_3$ as follows: 93.61, 96.91, 96.73, and one 78.75 with 20.16 per cent of $MgCO_3$ (ref. 66, page 531). Norton (ref. 47A, p. 374) gives an analysis of a stone at Lime City which shows a content of 99.11 per cent of total carbonates.

Gower township, referred to in the table on page 128, is number 80 north, range 4 west, and Sugar Creek is number 79 north, range 2 west.

Clinton County.—Clinton county is almost wholly in the dolomite area. An analysis of a sample taken from a quarry in the northeast part of the city of Clinton gives 59.44 per cent of $CaCO_3$ and 39.62 per cent of $MgCO_3$, total carbonates, 99.06 per cent (ref. 34); and one collected in the southeast quarter of section 27, Waterford township, 83 N., R. 2 E., contains 54.14 per cent of $CaCO_3$ and 41.58 per cent of $MgCO_3$, total carbonates, 95.72 per cent. Reference 57, page 395, in a section for a quarry near De

Witt, shows beds of dolomite and limestone in the same section. Figure 14 shows a view in one of the dolomite quarries at Lyons.

Delaware County.—The "Niagara limestone" of this county is chiefly dolomite and underlies nearly all parts of the county. Areas of limestone are found in the southeast quarter of section 8, Union township, 87 north, range 4 west, and along Prairie creek in sections 27, 28 and 29 of Coffins Grove township, west of Manchester. Along the bluffs near where Maquoketa river leaves the county and perhaps in other places there are also sev-

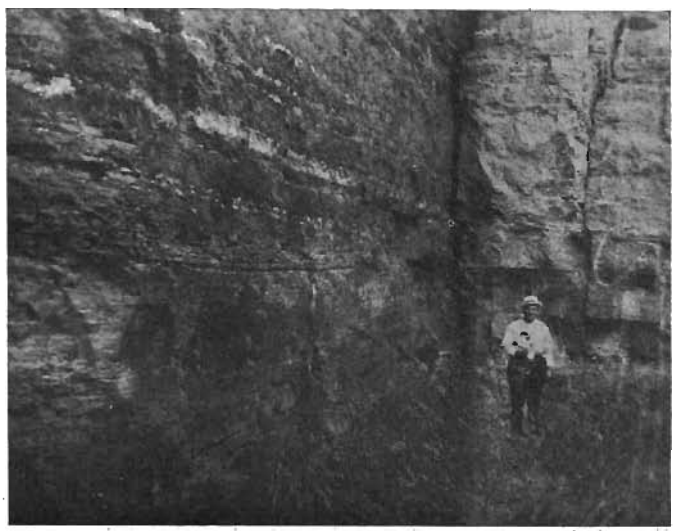


FIG. 14.—A quarry in dolomite at Lyons, Clinton county. Thin layers of chert nodules in the upper left quarter of the picture.

eral outcrops consisting chiefly of limestone. (See map, opposite page 130, and analyses, page 129.)

Chert occurs more or less extensively in nearly all of the outcrops in the county. In the quarry in the northwest quarter of the northwest quarter of section 6, Milo township, a few miles south of Manchester, chert and dolomite are found in nearly equal quantities. A large amount of chert is found also along a north-south ridge three to four miles east of Manchester and in several other places in the county.

Dubuque County.—Along the bluffs of Mississippi river at Spechts Ferry and at Zollicoffer Lake a good quality of lime-

stone is found. Several analyses show the rock in the former location to contain 75 to 90 per cent of calcium carbonate and from a fraction of one per cent to nearly seven per cent of magnesium carbonate. Analyses of six samples from Zollicoffer Lake (ref. 66, p. 533) show the following percentages of calcium carbonate respectively: 80.14, 77.93, 78.24, 84.16, 86.33 and 90.20.

At Eagle Point in North Dubuque and probably at several other places in the county beds of limestone are found alternating with beds of dolomite in the same quarry or outcrop. A strip

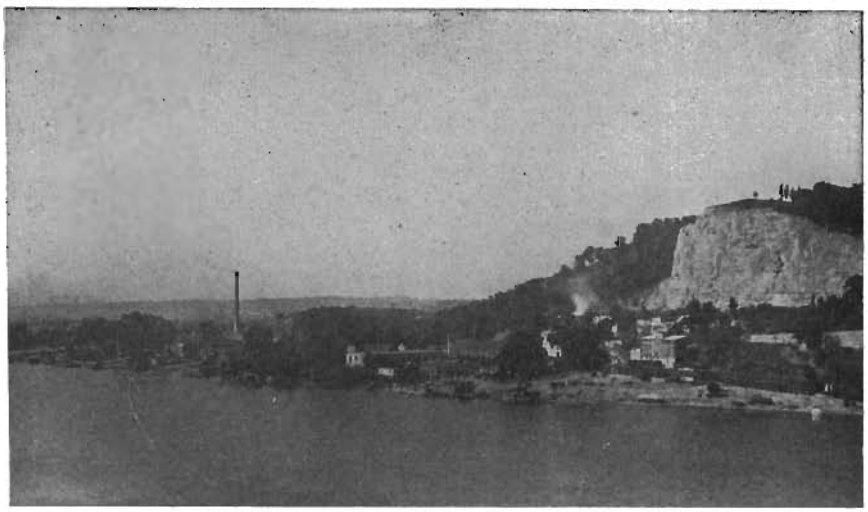


FIG. 15.—A view of the Eagle Point quarry taken from the bridge at Dubuque. Layers of limestone and of dolomite are found in this bluff.

about one township wide along Mississippi river contains some beds of limestone and some of dolomite promiscuously distributed. Underlying all of the upland to the west of this strip is the typical dolomite of northeastern Iowa. North Dubuque township referred to in the table of analyses is number 89 north, range 4 east, and the location referred to is the big quarry at the Mississippi river bridge at Eagle Point shown in figure 15. Taylor township is number 88 north, range 1 east, and Vernon township is in range 2 east, 88 north. The analysis given is that of screenings. An analysis (ref. 34) of face rock here (not given in the table, page 129) is $CaCO_3$, 55.35 per cent; $MgCO_3$, 40.97 per cent; total carbonates, 96.32 per cent.

Careful tests failed to show the presence of any considerable amount of phosphate in the limestones of the county.

Jackson County.—The outcrops and quarries of Jackson county are practically all in the dolomite area. In a few places in the county, as in an undeveloped area on North Maquoketa river in the east half of section 9, Brandon township, which is 85 north,

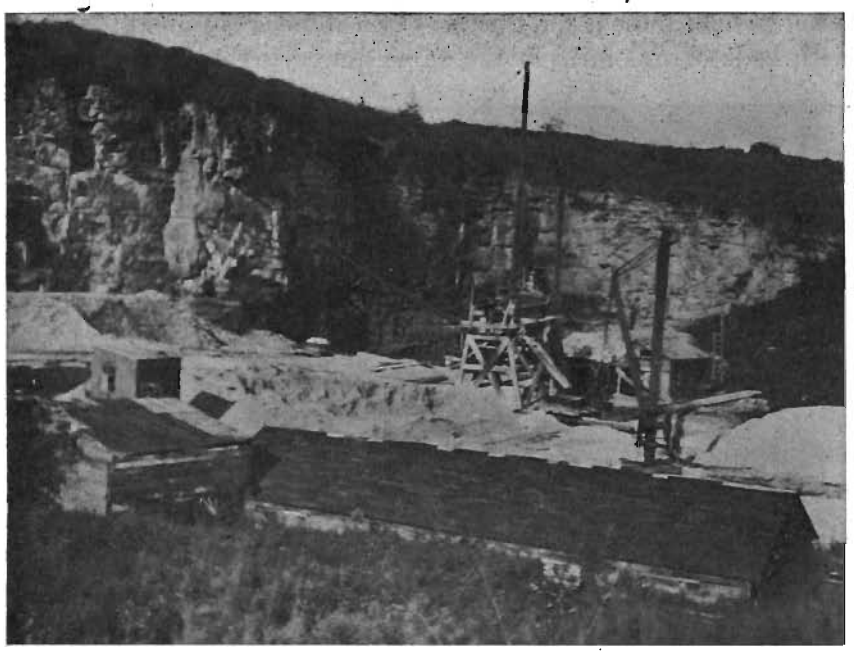


FIG. 16.—State quarry and crusher near Anamosa, Jones county. The rock is dolomite.

range 1 east, an area of limestone is found. The analyses given in the table on page 129 are from South Fork township, which is 84 north, range 2 east; and from Bellevue, which is township 86 north, range 4 east.

Johnson County.—Tests made some years ago at Iowa City show that the limestone at that town contains 87.79 per cent of calcium carbonate and 4.66 per cent of magnesium carbonate. The data given in the tables on page 129 refer to samples which were obtained from Jefferson township, which is 81 north, range 7 west; Big Grove township, which is 81 north, range 6 west; and East Lucas township, which is 79 north, range 6 west. These

places can be easily located on Plate VIII, opposite page 130. The total carbonates for the above locations are: Jefferson, 96.06 per cent; East Lucas, 95.48 per cent; and Big Grove, 94.53 per cent.

Reference 66, page 534, gives an analysis of limestone at "Iowa City" whose total carbonates aggregate 94.45 per cent.

Jones County.—The analyses of rock from Jones county which appear in the table on page 129 refer to specimens from Fairview township, which is 84 north, range 4 west, and from Cass township, which is 85 north in the same range. The rock in this county is practically all in the dolomite area and this locality has produced many excellent specimens of fossil forms from the quarries and outcrops along Maquoketa river.

The third analysis given in the table of analyses for Jones county, page 129, shows the composition of screenings from the locality (Stone City) described in the second line of the same table. The analysis in the fifth line of the same table shows the test made on screenings from the locality described in the fourth line. A view of the State quarry at Anamosa is given in figure 16.

Linn County.—The lime bearing rock of Linn county may be divided into two groups separated by an irregular line extending in a southerly direction approximately along the middle of range six west, passing near Coggon and Central City, crossing Cedar river just below Cedar Rapids and running nearly parallel to the river and one to two miles west of it. East of this line the hard rock is chiefly dolomite; west of it limestone is found as marked on the map, page 130. Screenings from the northeast quarter of section 15, Franklin township, tested as follows: impurities, 3.41 per cent; total carbonates, 96.58 per cent. See analyses page 129.

Grundy, Marshall and Tama Counties.—LeGrand township, Marshall county, is 83 north in range 17 west and Marion is number 84 north in the same range. Clay township, 86 north, range 17 west, in Grundy county, contains the only limestone outcrops of the county. They are located near Conrad and Beaman along the creeks and contain limestone suitable for use as a soil amendment. These beds are but a northward extension of the rocks which outcrop in western Tama and eastern Marshall counties.

There are several outcrops of a good grade of limestone in

Tama county north of Montour in Indian Village township, number 83, range 16 west, and these beds extend into Carlton township which is just north of Indian Village. The character of this rock is well represented by the analyses made from samples obtained at a quarry just across the line in Marshall county in LeGrand township, 83 north, range 17 west, and in Marion township, 84 north in the same range.

FIG. 17.—An old quarry along the north bluff of Iowa river in Marshall county. The rock is limestone.

Analyses of the rock at Quarry which are given in reference 66, page 535, show it to contain calcium carbonate as follows: oölite, 98.30 per cent; blue limestone, 97.95 per cent. The more definitely stratified limestone contains 90.04 per cent and also 8.08 per cent of magnesium carbonate. No appreciable amount of phosphate was found in the samples. Figures 17 and 18 give views of some of the quarries in Marshall county.

Muscatine County.—Muscatine is famous for its development of the pearl button industry and there are more than twenty button factories in the city. The "button dust" or waste material from these factories is shown by analysis to be 97.46 per cent pure carbonate, and therefore of unusually high quality.

Scott County.—The map on page 130 shows the dividing line between the limestone and dolomite areas of the county to extend

nearly east and west about five miles north of Davenport. The rocks shown at the outcrops and quarries around Princeton and Le Claire as well as all others north of this division line consist

FIG. 18.—A ledge of limestone showing lenses of chert (light color) along the bedding planes between the layers. Quarry one mile north of Le Grand, Marshall county.

of dolomite. The quarries at Bettendorf and Linwood, on the other hand, and in Buffalo, the southwestern township of the county, are in an impure limestone whose total carbonates range from 78.91 per cent at Buffalo to 87.78 per cent at Bettendorf, as is shown in the table of analyses on page 130. "Stone dust"

from these localities is sold in several nearby counties on each side of Mississippi river.

The analysis (ref. 34) in the second line from the top of the table on page 130 is for screenings from the Bettendorf quarries east of Davenport; that in the fifth line is for screenings from Dolese Bros. at Buffalo; and that in the bottom line of the same table is for screenings at the Linwood quarry.

Analyses of Limestone in Southeastern Counties

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Appanoose County						
Vermillion	SE. ¼ 26	8	250	4 – 6	Good	Yes	No	5.10	93.97	.93
Vermillion	SW. ¼ 25	5	100	4 – 6	Good	Yes	No	7.23	91.03	1.61
				Davis County						
Salt Creek	NE. ¼ 11	8	100	6	Good	1½ mi	Yes	11.22	87.61	1.17
				Des Moines County						
City of Burlington	SW. ¼ 33	40	500					66.38	29.49	4.13
				Henry County						
Center	SW. ¼ 17	20	300	4 – 5	Good	Yes	Yes	5.95	81.13	12.92
Center	Screenings (muddy at times)					Yes		27.81	68.39	3.80
Center	NE. ¼ 17	25	800	3 – 5	Good	Yes	Yes	9.21	77.36	13.43
				Keokuk County						
Van Buren	N. ½ 24 Center	8	150	3 – 4	Good	40rd	20rd	9.57	88.40	2.03
Warren	9 & 10	20	500	3	Poor	Yes	½ mi	25.48	73.29	1.23
Sigourney	NW.¼ 2	6	100	3	Good	40rd	40rd	4.23	94.19	1.58
				Lee County						
Montrose	NE. ¼ 36	30	300	3 – 6	shale	Yes	Yes	9.06	87.36	3.58
Montrose	NE. ¼ 36				shale	Yes	Yes	36.07	55.94	7.99
Charleston	SE. ¼ 5	4	60	3 – 6	Good	1 mi	20rd	9.52	88.22	2.26
Montrose	NW.¼ 13	30	500	3 – 6	shale	Yes	Yes	26.29	62.29	10.42
Montrose	NW.¼ 13	30			shale	Yes	Yes	36.39	48.60	12.21
Keokuk	SE. ¼ 26	25	300	4 – 6	shaly	Yes	Yes	18.91	72.73	8.36
Keokuk	SE. ¼ 26				shaly	Yes	Yes	26.02	68.28	5.70
				Mahaska County						
West Des Moines	SE. ¼ 35	8	200	4 – 6		1 mi	Yes	8.48	89.34	2.18
Scott	W. ½ 31	8	100	4 – 6	Good	1 mi	Yes	8.26	89.61	2.13
White Oak	Center 7	10	200	3 – 4	Good	Yes	Yes			

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
					Monroe County					
Pleasant	NW.¼ 1	8	100	3 – 4	Good	1 mi	20rd	6.29	90.63	3.08
					Van Buren County					
Van Buren	SW. ¼ 30	20	200	3 – 4	Good	1 mi	40rd	7.37	91.45	1.18
Harrisburg	4	10	150	3 – 4	Good	3 mi		4.54	90.92	4.54
Harrisburg	SW. ¼ 32	10	125	2 – 3	Good	2½ mi		8.06	89.53	2.41
Henry	SW. ¼ 3	8	100	2	Good	2 mi		3.3	94.12	2.58
Farmington	NE. ¼ 5	10	200	4 – 7	Good	40rd	80rd			
					Wapello County					
Columbia	SW. ¼ 7	8	100	6 – 8	Good	1 mi	40rd	5.72	93.20	1.08
					Washington County					
Brighton	NE. ¼ 30	15	200	2 – 4		Yes	Yes	3.96	94.19	1.85

SOUTHEASTERN COUNTIES.

In Davis, Keokuk, Lee, Mahaska, Van Buren and Wapello counties a high quality of white limestone is found in abundant quantities along Des Moines and Skunk rivers and along some of their branches. Practically all of the limestone in these locations is suitable for use as raw limestone fertilizer—the problem is simply one of getting the rock crushed to the proper degree of fineness and applying it to the soil according to its needs. See the table of analyses, page 138, for details, also map, page 140, for locations.

Lee County.—In Lee county small traces of phosphate were found as is shown in the descriptions given in the following section:

Section in McManus quarry at Keokuk

		Feet
1.	Limestone, weathered, yellow to brown, fossiliferous, containing brachiopods and *Archimedes;* traces of phosphate	4
2.	Limestone, gray to blue, beds two feet thick; phosphate in cracks	4
3.	Shale, clay parting; weak reaction for phosphate	¼
4.	Limestone, thick bedded	4
5.	Shale, blue	1
6.	Limestone, thin bedded; slight traces of phosphate	6
7.	Limestone, thick bedded, gray, a few small geodes in the upper part	8
8.	Limestone, gray, thick-bedded, below main quarry floor	5

Des Moines County.—In Des Moines county, around Burlington and elsewhere, the limestone in some places is mixed with clay. But there are also localities in which the limestone is nearly pure.

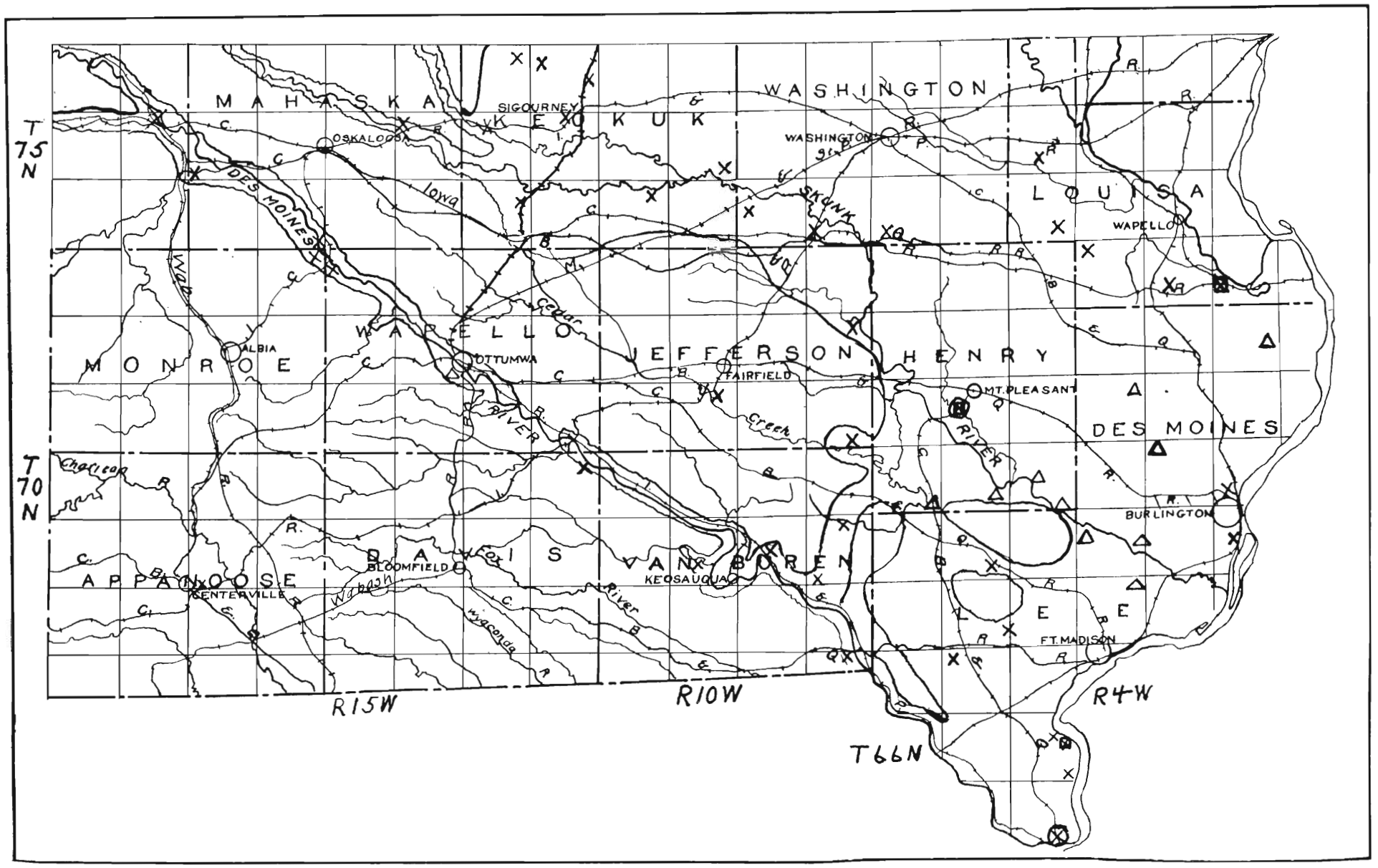
An analysis (ref. 66, p. 532) of a sample from Burlington (exact location not given), shows the specimen to contain 93.11 per cent of calcium carbonate and 0.84 per cent magnesium carbonate, total 93.95 per cent. The quality of this rock makes it extremely desirable for use as a fertilizer.

Henry County.—An analysis by Professor Harper of rock from the quarry in the southwest quarter of section 17, Center township, two and one-half miles southwest of Mount Pleasant, shows 81.13 per cent of $CaCO_3$ with 12.92 per cent of $MgCO_3$, total 94.05 per cent. Another sample from the northwest quarter of section 17, also analyzed by Professor Harper, contains 77.36 per cent of $CaCO_3$ with 13.43 per cent of $MgCO_3$, total 90.79 per cent. See the map, page 140, for locations.

Jefferson County.—The uppermost bed rock in the western three-quarters of Jefferson county is chiefly shale and sandstone which belong to the coal-producing group of sedimentary layers. The limestone occurs in a few places along the creeks and rivers in the localities shown on the map on page 140. Though no analyses of samples from this county are given in the tables, the same high grade of limestone that is found in Lee, Henry and Keokuk counties exists here.

Keokuk County.—The specimen from Warren township, 75 north, range 13 west, whose analysis is given in the table, is a sandy limestone. The western tier of townships contains numerous outcrops of sandstone, which is worthless as a fertilizer. Van Buren township is number 76 north, range 12 west, and Sigourney is the township just south of it. The total carbonates shown in the analyses are respectively, 90.43 per cent and 95.77 per cent.

Louisa County.—An analysis of a sample of limestone taken near Morning Sun (ref. 66, p. 534) shows a content of 97.02 per cent of calcium carbonate and one by Harper from the exposure south of Elrick Junction shows that the rock contains only 60.56 per cent of calcium carbonate with 34.47 per cent magnesium car-



MAP OF SCUTHEASTERN IOWA. AREAS OF LIMESTONE, DOLOMITE AND UNPRODUCTIVE AREAS ARE SEPARATED BY UNBROKEN LINES. OUTCROPS AND QUARRIES ARE SHOWN BY SAME MARKS AS IN PLATES VII AND VIII.

bonate, total 95.03 per cent, and 4.97 per cent impurities. The major part of the lime-bearing bed rock in the county is good, pure limestone.

Monroe County.—The only limestone outcrops of any size in Monroe county are in the northeast corner across Des Moines river from Eddyville. A test made from an outcrop about a mile west of Eddyville in the northwest quarter of section 1 shows the presence of 90.63 per cent of calcium carbonate, 3.08 per cent of magnesium carbonate, total 93.71 per cent, and 6.29 per cent of insoluble matter.

Wapello County.—In Washington township, sections 31 and 32, on the old coal mining property at Laddsdale, west of Eldon, is a ledge of limestone about twenty-four to thirty inches thick. As there are thick shales above and below the limestone it has no commercial value. Samples sent by the owner, Mr. W. R. Daum, were found by E. H. Wallace to contain: Impurities, 13.05 per cent; $CaCO_3$, 62.22 per cent; $MgCO_3$, 24.45 per cent; P_2O_5, 0.295 per cent; total carbonates, 86.77 per cent. See also the table of analyses on page 139.

Washington County.—Analysis shows that 94.19 per cent of calcium carbonate and 1.85 per cent of magnesium carbonate, total 96.04 per cent, with 3.96 per cent of impurities, constitute the proportions respectively in a sample obtained about a mile north of Brighton along the highway. This is in accord with the high tests made by nearly every sample secured in the southeastern counties of the state.

Wayne County.—Professor Harper's (ref. 34) analyses of samples obtained from the south half of section 36 in Wright township indicate 91.90 per cent and 77.95 per cent respectively of total carbonates. These ledges are thin and the outcrops are relatively unimportant. Limestone probably can be shipped in more cheaply than this rock can be crushed.

Analyses of Limestone in Other Counties

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Decatur County						
New Buda	NW.¼ 10	15	600	3	Good	40rd	Yes	12.48	85.43	2.09
				Harrison County						
Jefferson	N. ½ 19	6	50	10 –30	Good	40rd	Yes	5.98	84.75	9.27
				Madison County						
Madison	SE. ¼ 18	30	600	12	Good	Yes	80rd	8.88	86.46	4.66
Madison	S. ½ 16					Yes	Yes	18.88	73.52	7.60
Madison	N. ½ 21					Yes	Yes			
Madison	SE. ¼ 4	12	500	6 – 8	Good	Yes	Yes	9.85	88.24	1.91
Scott	NW.¼ 6	20	300	4	Good	1 mi	Yes	17.11	81.18	1.71
Walnut	NW.¼ 10	15	200	5 –10	Good	1 mi	Yes	11.78	86.05	2.17
				Marion County						
Red Rock	SW. ¼ 25	8	100	4 – 8	Poor	Yes	40rd	95.94	4.06	1.27
Clay	SE. ¼ 4	6	50	6	Good	40rd	40rd	8.82	91.18	2.99
				Montgomery County						
Sherman	W. ½ 27	12	200	3 –10	Good	Yes	20rd	7.53	91.14	1.33
Sherman	SE. ¼ 34	12	200	3 – 8	Good	Yes				

OTHER COUNTIES.

Decatur County.—There are several outcrops of limestone near Davis City and elsewhere along the slopes of Grand River valley in Decatur county. The quality of this rock is good, the percentage of calcium carbonate reaching 85 per cent as shown in the table of analyses above. The specimens analyzed were obtained near the railroad about two miles southwest of Davis City.

It seems that small crushers might be profitably operated in Decatur county in producing pulverized limestone for local use as a soil amendment.

Harrison County.—The outcrops of limestone in Harrison county are relatively unimportant even though the quality of material is good.

Marion County.—The outcrops of limestone in Marion county are most numerous along Des Moines river valley and its larger branches. The analysis given above is of a specimen from Clay township which was procured near Harvey and several

other large outcrops are found between Harvey and the former town of Flagler. A few half-covered exposures lie about three miles northwest of Knoxville, north of the railroad and southeast of Whitebreast creek. In the northeastern part of the

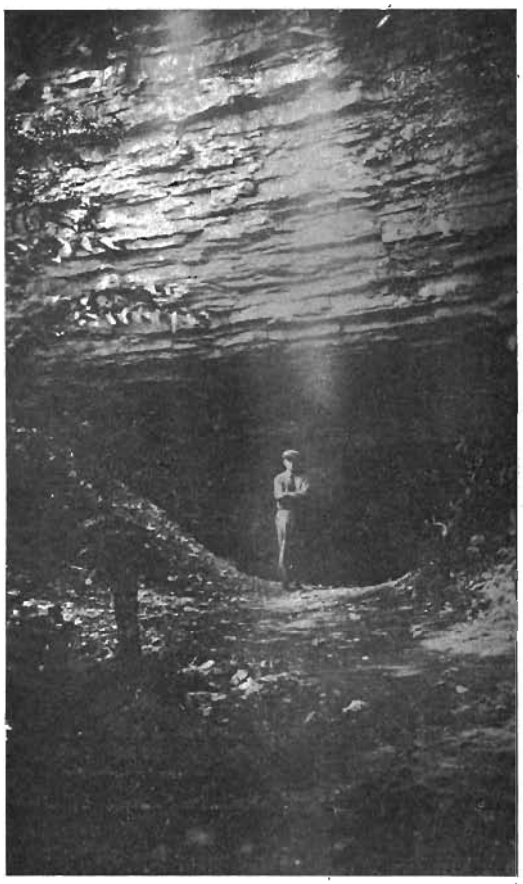


FIG. 19.—Limestone at the "Backbone" southwest of Winterset, Madison county.

county along Skunk river valley there are several outcrops of good limestone. All of the larger areas of white limestone in the county contain rock of high quality which will give excellent results when ground to a fine powder and used as fertilizer. The specimen analyzed from Red Rock township, see page 142, is a calcareous sandstone and is unfit for use as fertilizer. For other differences between sandstone and limestone see page 112.

Madison County.—Large quarries at Earlham and Peru and large outcrops in the vicinity of Winterset (see fig. 19) and in a few places in Clarke county south from Peru toward Davis City, Decatur county, and along Grand River valley to the Iowa-Missouri line, are found to produce an abundance of high grade limestone remarkably well adapted for use as a soil amendment. The

FIG. 20.—Bethany Falls limestone (Earlham). The exposure here illustrated is found on the south side of a projecting ridge of the upland in the southeast quarter of the northeast quarter of section 2 of Ward township, Clarke county.

quarries at Earlham are in Madison township and those at Peru are in Walnut township.

These ledges constitute the lower part of what is known among geologists as the Missouri limestone. This formation contains a very small amount of phosphate, as is shown in the description of an exposure in the quarry of the Peru Stone and Cement Company as follows:

Section at Peru, Madison county

		Feet
1.	Loess	3
2.	Glacial till, weathered and unweathered, partly blue	25
3.	Limestone, buff to yellow, much weathered, thick bedded, some nodules; gives weak reaction for phosphate	4
4.	Shale, a clay parting; gives weak reaction for phosphate	½ to 1
5.	Limestone, in 7 layers, compact, rust-filled cavities in upper foot; phosphate in joints and bedding planes	6
6.	Limestone, contains clay; very slightly phosphatic	1
7.	Limestone, beds 1 foot thick above to 4 inches thick below; gives weak reaction for phosphate in the cracks	5
8.	Shale, blue to black, greenish gray below; just beneath the main quarry floor	

Montgomery County.—In the vicinity of Stennett in Sherman township there are several small outcrops of limestone of good quality but the beds are so extensively intercalated with layers of clay and shale that they are in the non-commercial class.

Excepting the group of limestones extending from Earlham southward to Winterset, Peru and Davis City, there is little, if any, rock of commercial importance in southern Iowa west of Des Moines river.

New and Re-opened Quarries

When the use of ground limestone on soils becomes more general it may be necessary and profitable to re-open a large number of quarries that have not been worked for several years. The use of small crushers in producing an output of cheap pulverized limestone to meet local needs may require that new quarries be opened in many localities. The principal factors to be considered in selecting a location for a quarry are as follows:

FACTORS AFFECTING THE VALUE OF A QUARRY SITE.

1. The kind and quality of rock should be found by test to be that adapted to the uses intended.

2. The rock of the quarry should be free from lenses or layers of chert and from layers of sand and clay.

3. The area from which available stone may be obtained should be large.

4. The depth and kind of overburden or stripping to be removed should not be such as to require excessive expenditure.

5. The height of rock face or depth of quarry it will be possi-

ble to work should be sufficient for commercial development. Most successful quarries are fifteen feet high or more at the face.

6. The elevation of the quarry floor should be well above the water table or surface of the ground water.

7. The surface conditions should permit thorough drainage of the quarry and its suroundings.

8. Abundant space should be available for the disposal of waste materials.

9. It should be located as near as possible to where its product is needed.

10. It should be on or very near a highway and a railroad.

Producers of Agricultural Lime

The following firms have produced agricultural lime during the past four years:

Bartlett & McFarlane	Waterloo
Bettendorf Stone Co.	Bettendorf
Burlington Quarry Co.	19 S. 7th St., Keokuk
Cedar Valley Trap Rock Co.	Cedar Rapids
Dolese Bros.	Buffalo
Eagle Point Lime Works	Dubuque
Hale Roberts Stone Co.	Iowa Falls
Hawkeye Quarries Co.	Cedar Rapids
Keokuk Stone & Construction Co.	Keokuk
Linwood Stone & Cement Co.	Davenport
Mount Pleasant Crushed Stone Co.	Mount Pleasant
McManus Quarries Co.	Keokuk
Murphy Construction Co.	Louisville, Neb.
Peru Stone & Cement Co.	Peru
Quimby Stone Co.	Mason City
State Reformatory	Anamosa
Sugar Factory	Belmond
Sugar Factory	Mason City
Winneshiek County	Decorah

It is reported that agricultural lime is produced also at Earlham, Madison county; Gilmore City, Pocahontas county; Rutland, Humboldt county; Hurstville, Jackson county; near Arlington, Fayette county; on the Chicago, Milwaukee & St. Paul railway west of Marquette, Clayton county; and at Rock Valley in Marshall county.

At some of these places, the crushers are not operated every year and some of them run only during the summer season. At some of them the stone dust is a waste product but several of the companies have sold a thousand tons or more during one year.

The limestone waste from the sugar factories at Mason City and at Belmond is highly recommended for use as fertilizer.

Summary and Conclusions

1. Practically all of the thick beds of limestone in Iowa afford good material for use as a soil amendment and most of this rock is of high quality for this use.
2. Some areas in nearly every county in Iowa need to have limestone applied.
3. The supply of limestone is abundant and its distribution is favorable for its use wherever it is needed.
4. There is some phosphate in Iowa limestones but it is present in quantities too small to have a commercial value.
5. The marls of Iowa are neither sufficiently rich nor abundant to have much economic value.
6. There is no possibility of obtaining potash for fertilizer from the residues of Iowa lakes.
7. The gypsum deposits of Iowa are of the best quality for use as "Land plaster".
8. At present the pyrite of Iowa has no value.
9. Some of the peat of Iowa could be used as a fertilizer filler and some of it may have value as an ingredient of stock food.
10. In many localities peat may be used for fertilizer as barnyard manure is used but with less satisfactory results. Its greatest value for this purpose probably is on soils containing alkali and on sandy soils. It contains about two per cent of nitrogen and less than one per cent each of phosphorus and of sulphur.
11. The black, fine and well-rotted varieties of peat are more useful as fertilizer than the hard brown and fibrous ones, which decay too slowly.
12. The peat-producing areas of Iowa are in the north-central part of the state. Peat is found in a few other localities in river bottoms.

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