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STATE GEOLOGICAL SURVEY *of* KANSAS

RAYMOND C. MOORE, State Geologist
KENNETH K. LANDES, Assistant State Geologist

# VOLCANIC ASH RESOURCES *of* KANSAS

By

KENNETH K. LANDES

BULLETIN 14

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# Volcanic Ash Resources of Kansas.

## INTRODUCTION.

In recent years Kansas has led the United States in the production of volcanic ash. Although still a small industry, the output of this material is rapidly increasing, and gives promise of more expansion in the near future. Consequently it was believed that a bulletin describing the resources and uses of volcanic ash would render service to the citizens of Kansas.

The writer spent a large part of the summer of 1927 in central and western Kansas studying the resources of the state in regard to volcanic ash. During the following winter the samples collected in the field were subjected to considerable laboratory research. The results of this study are included in the present paper.

The writer is indebted to the producers of volcanic ash and the owners of deposits for their unfailing courtesy and assistance. Special thanks are due to: J. H. Cowell, vice president, Pumicite Company of St. Louis; R. G. Moss, formerly an engineer for the Pumicite Company; R. E. Colburn, Satanta; J. C. Blackburn, Tasco; P. B. Garrot and C. R. Bird, of Atwood; E. A. Hanzlicek, Wilson; S. W. Gibson, Wakeeney; J. G. Tubbs, Turon; C. D. Hickok, Ulysses; L. W. Kesler, Wichita; H. T. Martin, Lawrence; and N. W. Bass, Washington, D. C.

### Nomenclature.

Volcanic ash is composed of excessively fine glass or lava fragments. It is produced by volcanoes, but due to the lightness of the individual particles it may be carried by the wind many hundreds of miles from its source. A great number of names have been used for this material. Among them are volcanic dust, pumice, pumicite, geyserite, silica, and feldspar. Because volcanic ash is not a product of combustion a number of geologists object to the word ash. But the term predominates in the literature and is defined by the dictionaries, so it will be used throughout this report. Pumice refers to larger vesicular rock-glass fragments of similar composition and origin. When ground it is very similar in its properties to volcanic

ash. The United States Bureau of Mines, in its statistical publications, makes no distinction between the two, calling everything pumice. Geyserite is mineral matter deposited by geysers about their vents, and the term was applied to volcanic ash in Nebraska when it was first discovered and its origin misconceived. Unfortunately the prevailing field term in Kansas for volcanic ash is silica. Chemically speaking, ash is composed largely of silica, but this compound is not present as free silica, but in the form of silicates, which is quite another matter. In one part of Kansas the terms feldspar or spar are used, which are likewise entirely erroneous.

## Distribution.

There are a number of regions in North America where volcanic ash occurs. Deposits found in Kansas belong in the Great Plains province. Other states belonging in this province are Oklahoma, eastern Colorado, Nebraska, South Dakota and western Iowa. The thickest deposit known to the writer is located at the eastern end of the Oklahoma panhandle, near Gate. Here 30 feet of pure white ash is exposed in a bluff, and it is claimed that the same material has been found by drill to extend 50 feet below the bottom of the exposure, making a total thickness of 80 feet. Farther eastward and southward, in northern and central Oklahoma, are a number of other deposits. Ash is known to occur at several localities in the Great Plains portion of Colorado, near the Kansas line.[1] Deposits are found over a large part of Nebraska, with the largest in Lincoln, Harlan and Furnas counties.[2] The occurrences in Iowa and South Dakota are of slight importance.

To the west is the Rocky Mountain province, with ash deposits in Colorado, Idaho and Montana. Along the Pacific coast both pumice and volcanic ash are found surrounding a number of the recent volcanoes of that region. On the Alaskan peninsula is a large amount of ash produced by the violent eruption of Mount Katmai in 1912. Similar deposits may be found along Pacific South America, eastern Asia, in the Mediterranean region and elsewhere where volcanoes have been active.

Kansas leads the United States in the annual production of volcanic ash (see page 49 for production statistics). Most of the deposits in Kansas are in the western part of the state near the 100th

1. R. D. George. Informal communication.
2. Barbour, E. H. Nebraska Pumicite: Neb. Geol. Surv., vol. 4, pt. 27, 1916.

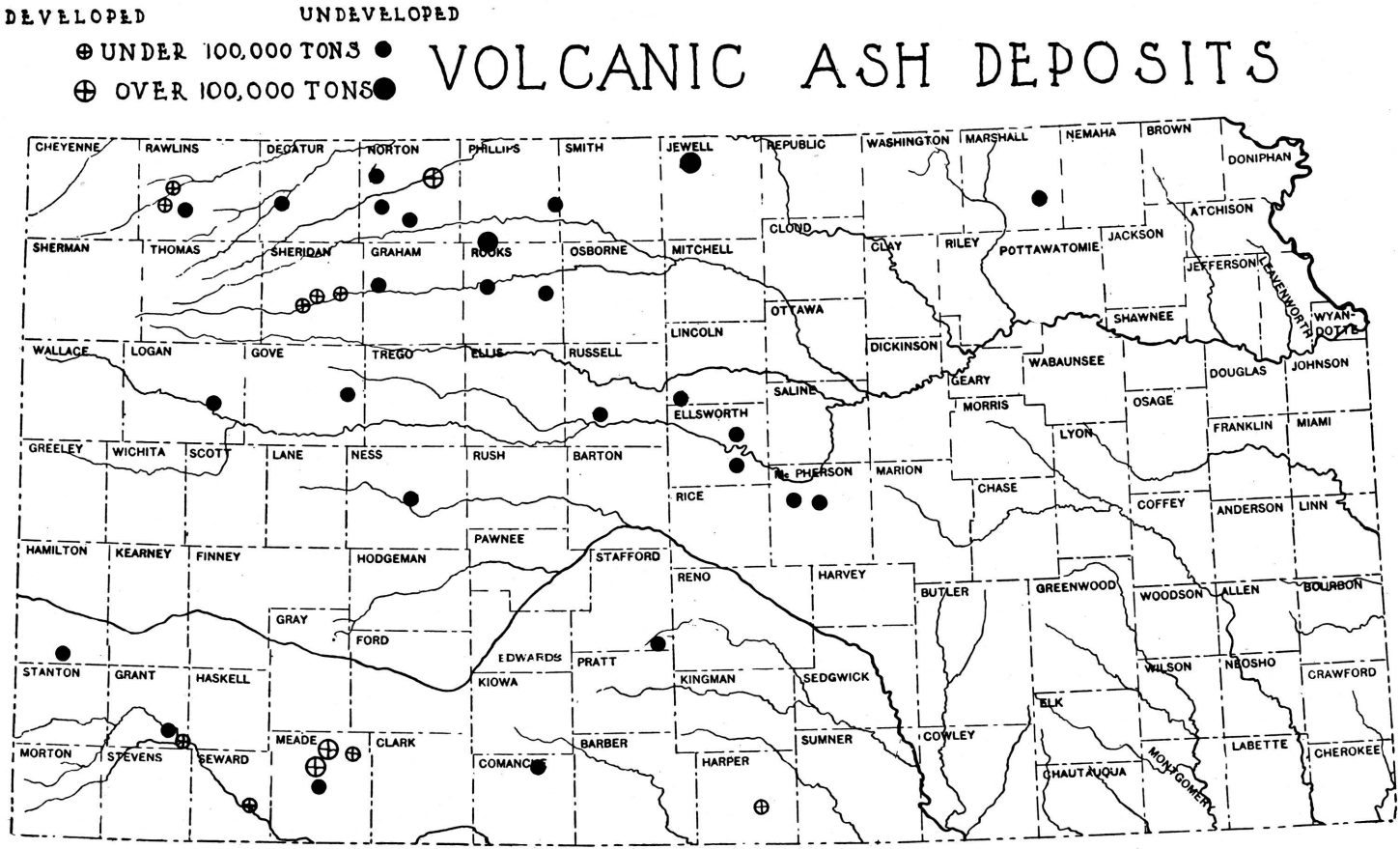



PLATE I.—Map of volcanic ash deposits in Kansas.

meridian. Small deposits are found in central Kansas, in Ellsworth and McPherson counties, while the easternmost occurrence is in the northeastern part of the state along the Nemaha-Marshall county line. The largest known deposits in Kansas occur in Meade, Norton, Phillips and Jewell counties. The first two counties are at the present time producing, while Phillips and Jewell counties are not. Counties with either a small present production or known possibilities for production in the near future are Sheridan, Harper, Seward, Grant, Rawlins, Comanche, Smith, Ellsworth, Graham and McPherson. In addition there are a number of counties in which deposits are too small or in such inaccessible places that they could not be considered as having commercial possibilities at present. The list follows: Hamilton, Russell, Ness, Logan, Gove, Nemaha, Decatur, Rooks, Haskell, Lane, Sherman, Wallace, Pratt, Lincoln and Stafford.

## General Description.

### Deposits.

The volcanic ash deposits of Kansas are usually widely separated and completely isolated. Nowhere may the ash be considered a stratigraphic unit. Neither is it of any quantitative importance as compared to the volume of other types of rocks in this region. The ash deposits range in area from a few square feet to a quarter section, with the average a few acres. Thickness varies from a few inches to 20 or 25 feet, and in a single deposit the character of the material may be extremely variable. As a general rule the maximum thickness is found somewhere near the center of the deposit. From that point outward the thickness may diminish, becoming nothing at the border, or it may remain the same, the deposit grading into loess or sand around the edges. A similar gradation is sometimes observed between the ash and the overlying and underlying material. Careful prospecting of deposits by means of extension augers has shown in a number of instances the presence of hills of underlying material which reduce the thickness of the deposit and lessen greatly its tonnage.

With but few exceptions the volcanic ash deposits are strongly cross-bedded. They also show very definite banding due to alternating layers of coarse and fine material. These conditions are produced by a varying wind direction and by the sorting effect of this agent. Horizontally bedded ash is found in Hamilton county and in the older deposits of northwestern Kansas.

The overburden which must be stripped off to make the ash available ranges from nothing to 20 or more feet in thickness. It usually consists of soil which either has slumped or has been washed over the deposit from near-by higher points. At a number of deposits the overburden consisted of impure ash. Here wind and running water has reworked the material at the top of the deposit, adding soil, clay, or sand and making that part of the ash unfit for commercial use. Very often a thin veneer of stream-carried pebbles covers the deposits. In Harper county such a veneer consisted of subangular to spherical quartz, rhyolite, quartzite, and basalt pebbles, with a few angular limestone fragments. The pebbles probably came from the Rocky Mountains, while the limestone was picked up near by. In northwestern Kansas, especially in Norton county, some of the deposits are of an older age and underlie grits or "mortar beds." In this case the hardness of the overburden prohibits the commercial utilization of the ash beneath.

The position of the ash deposits with regard to local topography is a factor of importance to the prospector. The ash was mainly blown from the southwest and sought refuge in depressions. Subsequently normal stream erosion destroyed many of the deposits.[3] It also altered considerably the local topography, making difficult the formation of general rules in regard to the relationship between ash deposits and the hills and valleys of to-day. Where the country was very flat, as in the southwestern corner of Kansas, the ash could not find protected depressions in which to lodge, hence such areas hold little promise in the search for new deposits. On the other hand, central and eastern Kansas offered much more irregular topography, and what ash did reach this area found plenty of depressions in which to accumulate. But erosion by running water has been more severe in eastern than in western Kansas, so most of these deposits were destroyed. The happy medium seems to have been near the 100th meridian, where there was sufficient relief to allow ash accumulation and insufficient erosion to destroy all the deposits. Where the topography has changed but little since the ash-depositing period the larger deposits are usually found on the southwest side of the valleys or, in other words, on the northeast (leeward) side of the divides. This is true for the larger stream valleys, for they were in existence before the period of ash deposition. But the smaller streams and tributaries, in their unceasing growth headward, may have so changed a region geologically in recent

3. The detailed steps involved in the formation of volcanic ash deposits are given in the section on origin at the end of this chapter.

time that deposits are located without regard to the present topography, occurring even on top of minor divides.

## Volcanic Ash.

### Megascopic description.

The volcanic ash in Kansas, when pure, varies in color from white or light gray to bluish gray. When impure it may be stained yellow or brown. The pure ash is readily distinguishable from all other substances. It is similar in appearance to finely powdered glass, and when placed in the sunlight sparkles brightly. It does not dissolve in acid with effervescence as does limestone or chalk. It settles readily in water, whereas clay will remain in suspension for a long period. Some of it is so fine that merely breathing on it will blow it into the air. Under a lens the extreme angularity and glassy nature of the material becomes apparent. This angularity makes volcanic ash an efficient scouring agent. If the ash is impure the glassy fragments may be coated with clay or iron oxide, in which case a microscopic examination may be necessary to definitely determine the material.

In certain places ground waters containing calcium carbonate in solution were very active. They precipitated the carbonate between particles of volcanic ash while working through the deposit. The result was a cementation of ash into coherent aggregates, and in some deposits the cementation produced countless small irregular lumps. In others cementation occurred outward from a center or nucleus in a symmetrical fashion producing forms known as concretions. Four main types of concretions were observed in the Kansas deposits. Representatives of the first type known as "fossil bones" or "stalactites," are long and cylindrical in shape. The cross section is oval or circular and often contains concentric markings like the rings on a tree. The second variety consists of ball or discoidal concretions. These also exhibit concentric structure. The third type is botryoidal in form. Separate ball concretions are cemented together like a snow man or a bunch of grapes. The fourth form of concretion may be called the "plug and sill" type. It consists of tabular parallel masses which extended out horizontally into the more permeable layers of volcanic ash which are tied together by a vertical plug. Any of these types may exhibit a pimply surface due to the addition of countless minute concretions.

All of the cemented volcanic ash aggregates are hard and are screened out and rejected before the material is marketed. Inasmuch as they consist dominantly of ash it would be possible to

crush them and market the product, but it is doubtful if the result would justify the increased expense.

### MICROSCOPIC DESCRIPTION.

Under the microscope volcanic ash looks like powdered glass. Scattered among the glass particles are occasional grains of feldspar with a small amount of quartz. In a few samples examined by the writer other minerals such as muscovite mica were present, but these are rare. The glass fragments are completely isotropic. Shapes vary, but the angularity is always pronounced. The majority of particles are triangular and elongated, producing a dagger-like figure. Some are four- and five-sided but with the corners invariably sharp. Many show a fluted structure with the corrugations usually parallel to the longer side. Occasionally a glass fragment contains a small liquid or gas bubble inclusion.

The volcanic ash samples collected by the writer were much alike, with the exception of one from southern Hamilton county. Most of the fragments in this sample were crystalline, consisting of feldspar (largely microcline) and quartz. As this deposit appears to lie nearer to the source than other Kansas ash beds the tendency of the crystalline material in the ash to settle first, because of slightly higher specific gravity, may account for the characters here observed. A few of the samples from elsewhere were impure and contained clay or limonite.

Thin sections of the concretions were made and examined under the microscope. They showed a mosaic of ash particles with large amounts of calcite cement. The orientation of the calcite was the same over large areas, showing the remarkable crystallizing power of this mineral. The ash must have been extremely incoherent before cementation, as the calcite fills numerous large voids in the jackstraw aggregate of glass fragments. A few differences were noted between the thin sections of the concretions in the older ash of Norton county and those from elsewhere. In the former instance there was more soda feldspar present and the crystals were much larger. Also there were a few fragments of what appeared to be triturated cone material which were not observed in the younger ash. This is taken as evidence of greater violence during the eruption of the older ash. In a deposit in Rawlins county, similar in age to those in Norton, the volcanic ash was compact throughout. A thin section of this material was very similar to the section of the Norton concretion. Evidently at this locality calcium carbonate cemented the entire deposit instead of a very small part.

TEXTURE.

An important factor in the value of a volcanic ash deposit is the degree of fineness of the ash particles. A deposit which will yield a high percentage of ash smaller than 300-mesh (under .046 mm. diameter) is more valuable than a deposit in which most of the ash lies between 100- and 200-mesh (.074-.147 mm.), other things being equal, for the owner of the former can screen his material and get a relatively high price for his finest grade.

While engaged in field work in preparation for this report the writer secured samples of ash from every deposit visited; these were taken into the laboratory and further studied. The attempt was made in sampling to secure about 100 grams (one-fifth pound) of ash which would be characteristic of the deposit as a whole. To accomplish this a vertical groove was cut from top to bottom in a fresh face, and the ash thus broken out was taken as the sample. This secured a representative vertical section. Horizontal changes in texture were disregarded as they are usually slight. In poorly exposed deposits the best available sample was secured, which may differ considerably from the true average.

In the laboratory the 100-gram sample was thoroughly dried by a vacuum dessicator and then screened. The diameter of the screen was 6 inches and the meshes were 20, 100, 200 and 300. The sample was placed in the 20-mesh screen with the higher meshes in sequence beneath. Each sample was subjected to three minutes of vigorous screening. At intervals the lid was removed and the friable chunks lying on the 20-mesh screen were broken down with the fingers or a rubber pestle. These are slightly compacted aggregates of ash which would be readily broken up in the revolving cylindrical dryer used in refining commercial ash. The unfriable particles are either ash aggregates tightly cemented with calcium carbonate, or pebbles present as an impurity. In either case they constitute waste.

At the completion of the screening operation the fractions remaining on each screen were removed and weighed and the percentages computed. An index number was secured for each deposit by adding together the percentage of ash caught on the 200-mesh screen plus twice the percentage caught on the 300-mesh plus four times the percentage passing through the 300-mesh screen. The finer grades were weighted more heavily because of their greater value. The purpose of the calculation was to give a single number which would be indicative of the textural quality of the deposit. In the accompanying table the mechanical analyses of all the sam-

*Table of Screen Analyses of Kansas Volcanic Ash.*

| Rank. | Deposit and Location. | Over 20 mesh over .833 mm. | 20–100 mesh .833–.147 mm. | 100–200 mesh .147–.074 mm. | 200–300 mesh .074–.046 mm. | Under 300 mesh under .046 mm. | Index No. |
|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | |
| 1 | C. May's farm near Beardslee, Rawlins county | 0.15 | 3 | 11 | 28 | 58 | 299 |
| 2 | Morland, Graham county | 0.4 | 2 | 12 | 36 | 45 | 281 |
| 3 | Western Spar Products Co. mine, southeast Grant county | 0.2 | 5 | 18 | 25 | 52 | 276 |
| 4 | Lyman farm, near Beardslee, Rawlins county | 0.3 | 4 | 17 | 40 | 39 | 253 |
| 5 | Ewer's farm, Tasco, Sheridan county | 1.4 | 15 | 14 | 28 | 42 | 238 |
| 6 | Quinter, Gove county | 0.5 | 2 | 26 | 40 | 32 | 233 |
| 7 | Oberlin, Decatur county | 0.6 | 13 | 23 | 35 | 28 | 205 |
| 8 | Speed, Phillips county | 0.1 | 14 | 26 | 33 | 27 | 200 |
| 9 | Vogel's farm, north of McPherson, McPherson county | 0.8 | 11 | 31 | 33 | 24 | 193 |
| 10 | J. C. Blackburn, Tasco, Sheridan county | 0.3 | 12 | 34 | 29 | 25 | 192 |
| 11 | Tubb's farm, southeastern Stafford county | 0.1 | 8 | 28 | 48 | 16 | 188 |
| 12 | C. P. Larson, north of McPherson, McPherson county | 0.1 | 30 | 1 | 52 | 17 | 173 |
| 13 | Soliday place, near Burr Oak, Jewell county | 0.45 | 25 | 27 | 24 | 24 | 171 |
| 13 | Hudson place, Kanopolis, Ellsworth county | 0.1 | 7 | 41 | 39 | 13 | 171 |
| 15 | Meade, Meade county | 1.0 | 22 | 34 | 22 | 21 | 162 |
| 16 | Gus Larson, northwest of McPherson, McPherson county | 0.2 | 23 | 31 | 27 | 19 | 161 |
| 17 | Northeast of Hoxie, Sheridan county | 0.4 | 15 | 42 | 29 | 14 | 156 |
| 18 | Hanzlicek property, southwest Lincoln county | 0.6 | 15 | 41 | 29 | 14 | 155 |
| 18 | North of Burr Oak, Jewell county | 0.08 | 16 | 37 | 35 | 12 | 155 |
| 20 | Cudahy mine, Meade county | 0.1 | 18 | 42 | 27 | 13 | 148 |
| 20 | Southwest of Atwood, Rawlins county | 0.2 | 25 | 28 | 34 | 13 | 148 |
| 22 | South-central Russell county | 15.0 | 14 | 30 | 25 | 16 | 144 |
| 23 | Western Nemaha county | 1.5 | 33 | 25 | 24 | 17 | 141 |
| 23 | Fowler, Meade county | 0.1 | 24 | 41 | 20 | 15 | 141 |
| 25 | Southeastern Logan county | 2.5 | 16 | 37 | 40 | 5 | 137 |
| 26 | Dellvale, Norton county | 0.4 | 24 | 39 | 26 | 11 | 135 |
| 27 | Wilmore, Comanche county | 1.0 | 27 | 39 | 19 | 14 | 133 |
| 28 | South of Norton, Norton county | 1.8 | 29 | 38 | 21 | 10 | 120 |
| 29 | Northwest of Burr Oak, Jewell county | 0.18 | 29 | 38 | 27 | 6 | 116 |
| 29 | Calvert, Norton county | 0.4 | 27 | 44 | 22 | 7 | 116 |
| 31 | Ness City, Ness county | 22.0 | 23 | 20 | 24 | 11 | 112 |
| 32 | Kensington, Smith county | 0.3 | 30 | 45 | 20 | 5 | 105 |
| 32 | Kismet, Seward county | 1.0 | 30 | 40 | 22 | 7 | 105 |
| 34 | South of Hoxie, Sheridan county | 2.5 | 39 | 34 | 18 | 7 | 98 |
| 35 | Woodston, Rooks county | 0.0 | 44 | 40 | 8 | 8 | 88 |
| 36 | Anthony, Harper county | 3.5 | 42 | 41 | 12 | 2 | 73 |
| 37 | Southern Hamilton county | 13.0 | 39 | 39 | 7 | 2 | 61 |

ples studied are given in order of their index numbers, with the highest (representing the finest ash) at the top.

Several points must be emphasized in regard to these analyses. One is that in a majority of deposits visited the ash had not been opened up by mining operations. Consequently the sample secured was taken from the surface and may not have been representative of the deposit as a whole. Due to the sorting action of the wind the size of the ash particles is liable to vary from layer to layer, so material at the surface may be coarser or finer than the average of the deposit. Another important point is that from 5 to 50 per cent of the ash caught on the 100-mesh screen is composed of minute ash aggregates which were not broken down in the screening process. However, they would be separated into individual particles by commercial milling, which would increase the percentage of finer ash and decrease the relative amount of coarse. For this reason, then, the screen analyses recorded in the table are not always indicative of the true texture of the ash. The third point to remember is that the ranking given the deposits is on the basis of texture only and has nothing to do with other extremely important factors, such as size of the deposit, purity, etc. The presence of clay would have an unfavorable effect upon the value of the deposit, and yet it might have little or no effect upon the screen analysis, for clay particles are likewise very fine.

### CHEMICAL NATURE.

Volcanic ash consists of liquid rock which has been blown to minute bits and suddenly chilled. Because of the rapid cooling crystallization cannot take place and a glass results. However, if crystallization had already started in the liquid rock before its trituration, fragments of those mineral crystals will be mixed in with the rock glass. In Kansas the volcanic ash consists of about 90 per cent rock glass and the remainder the mineral feldspar. Rock glass is a solid solution of silicates. Combining compounds are alumina, soda, potash, magnesia, lime, and iron oxide. Feldspar consists of aluminum silicate with potash, soda, or lime. The potash and soda varieties of feldspar were the only ones present in the samples studied. The silica content of the volcanic ash found in Kansas averages 73 per cent. An analysis of the ash from the Western Spar Products Company mine near Satanta, Kan., follows:[4]

4. Analysis by Western Research Corporation, Denver, Colo. Copy furnished through courtesy of R. E. Colburn, Satanta.

| | Per cent. |
|---|---|
| Silica ($SiO_2$) | 72.30 |
| Iron oxide ($Fe_2O_3$) | 1.40 |
| Alumina ($Al_2O_3$) | 12.20 |
| Lime (CaO) | trace |
| Magnesia (MgO) | .58 |
| Potash ($K_2O$) | 3.00 |
| Soda ($Na_2O$) | 6.52 |
| | 100.00 |

The following incomplete analyses were furnished by the Union Pacific railroad through E. C. Hoag, industrial agent:

| | Tasco, Sheridan county. Per cent. | Morland, Graham county. Per cent. |
|---|---|---|
| Silica | 73.75 | 74.30 |
| Ferric oxide | 2.20 | 2.00 |
| Alumina | 13.20 | 14.40 |
| Lime | 1.30 | 0.20 |
| Magnesia | 0.18 | 1.00 |
| Loss on ignition | 4.60 | 4.35 |
| Undetermined (probably potash and soda) | 4.77 | 3.75 |
| | 100.00 | 100.00 |

The commonest impurity liable to be present in volcanic ash is calcium carbonate. This substance cements the ash particles together in a manner already described. Its presence can be detected by immersing the lumps in acid, a vigorous effervescence denoting the presence of the carbonate. If the lump goes entirely into solution it is all calcium carbonate or limestone. Other common impurities are sand which is usually composed of quartz (silica), and clay consisting of hydrous aluminum silicates.

## Age.

It has already been implied that there are two distinct ages of ash in Kansas. The younger ash is the more abundant. It is white in color and entirely unconsolidated except where cemented by calcium carbonate into concretions. As it contains no fossils its age must be determined from its associations. In northern Kansas and Nebraska this ash occurs within or under loess. In McPherson county the same ash overlies sands and gravels of the McPherson formation, a river deposit of early glacial times.[5] Volcanic ash definitely older than the Iowan (Mid-Pleistocene) age has been found in Iowa.[6] Both the loess and the McPherson formation are

5. According to Erasmus Haworth (Univ. of Kan. Geol. Surv., vol. II, p. 289) a stratum of volcanic ash occurs within a clay member of the McPherson formation.

6. Kay, G. F.. Informal communication.

early Pleistocene in age, so the white ash must likewise be early Pleistocene.

Deposits of older ash are found in Norton, Decatur and Rawlins counties (northwestern Kansas), in Nebraska, and in the Rocky Mountain belt of Colorado, Montana and Idaho. It is much more compact than the younger ash, varies from gray to bluish gray in color, and is often referred to as blue ash. This ash occurs in the Kansas Tertiary between "mortar beds" of the Ogalalla formation, which is referred by Darton to the late Miocene or Pliocene.[7] Volcanic ash also occurs in the Oligocene of Nebraska and South Dakota, and in the Paleozoic formations of Oklahoma.[8]

## Sedimentation.

The great majority of Kansas ash deposits, in fact almost all those of Pleistocene age, owe their existence to wind action. Evidence for this conclusion lies in the cross-bedded character of the ash, in its incoherent condition and its areal, topographic and stratigraphic relations. Cross-bedding is found in both deltaic and wind-blown deposits, but in the former instance the material settles in water, becoming much more compact than is the case with most of the Kansas ash. A cross section through a snowdrift shows structure similar to that exhibited by the usual Pleistocene deposit in Kansas.[9] In Hamilton county, near the western border of the state, the ash is compact and in slabby layers, and was undoubtedly deposited under water. The Tertiary ash in Norton county is likewise compact and horizontally bedded, so it, too, is probably subaqueous in origin.

There were two stages in the formation of the ash deposits. In the first stage the ash was erupted from a distant volcano and settled down over the Great Plains, covering parts of Colorado, Oklahoma, Kansas and Nebraska to a slight depth. This primary deposition was similar to that occurring on the Alaskan peninsula and the island of Kodiak during the eruption of Katmai in 1912.[10] Following this the wind worked over the ash, building up dunes or drifts and driving them before it until they dropped into a stream and were dissipated or until they found secure lodgment on the lee-

7. Darton, N. H. Syracuse-Lakin Folio: U. S. G. S. Folio No. 212, 1920.

8. Gould, C. N. Informal communication.

9. R. T. Griggs (Nat. Geog. Mag.; Jan. 1917) likens the ash dunes formed by the wind on the island of Kodiak (Alaska), following the eruption of Katmai, to snowdrifts.

10. Martin, Geo. C. National Geographic Magazine; Feb. 1913. When Krakatoa (Dutch East Indies) erupted in 1883 ash fell on board a ship 855 miles away at the rate of 1 inch per hour for three days.

ward side of a ridge[11] or in some depression which they may have completely filled, thereby diverting the normal drainage. The ash deposits found to-day are those which were best protected from destruction by further wind action and running water. Without doubt most of the ash was driven into the valley bottoms where the streams carried away this excessively fine material.

## Origin.

A discussion of the volcanic ash deposits of Kansas would not be complete without some consideration of the origin of this material. That it came from a volcano or a group of volcanoes there can be no doubt as it is similar physically, chemically and microscopically to ash thrown out by our present-day volcanoes, and it is entirely dissimilar to any other known natural substance. But inasmuch as no recent volcanoes are known in Kansas, or to the south, north or east of this state, we must look westward for the source.

Before looking for the actual volcano we can derive considerable knowledge from an intensive study of the deposits themselves. In this discussion only the origin of the Pleistocene ash will be considered for the writer's data are incomplete in regard to the Tertiary deposits. The area covered by the Pleistocene ash is fan-shaped with the point of the fan toward the southwest. Evidently the ash was blown from that direction. Further, as a general rule the coarser or heavier ash lies to the southwest of the finer ash, which, because of its lighter weight, would travel farther before settling out of the atmosphere. With one exception the highest percentages of fine ash are found in the northern counties and in McPherson county, in eastern Kansas. A line drawn through these localities makes a rough arc with its center to the southwest. The coarsest ash of all is found in the subaqueous deposit in Hamilton county previously mentioned. The ash farthest removed from the source is found in northeastern Kansas, in Nemaha county. This is not the finest ash, however, for in the long distance it has traveled it has become contaminated by impurities which lower its grade and make it of medium rather than exceptional fineness. Barbour[12] in Nebraska and Buttram[13] in Oklahoma have both noted a general decrease in size of ash particles from west to east.

If the prevailing winds of to-day are similar to those of the past

11. Barbour, E. H. Neb. Geol. Surv., vol. 4, pt. 27.
12. Barbour, E. H. Nebraska Pumicite: Neb. Geol. Surv., vol. 4, pt. 27, 1916.
13. Buttram, Frank. Volcanic Dust in Oklahoma: Okla. Geol. Surv., Bul. 13, 1914.

we have further evidence that the producing volcano or volcanoes must have been to the southwest. The accompanying sketch contains a wind rosette for the last five years, showing that the prevailing wind in Kansas to-day is from the southwest. This wind is most important during five months of the year. Other common winds are the northwest and south. If the wind residuals be plotted and the resultant taken, as also shown on the sketch, it will be seen that the net effect of the wind in Kansas is to shift material to the north-

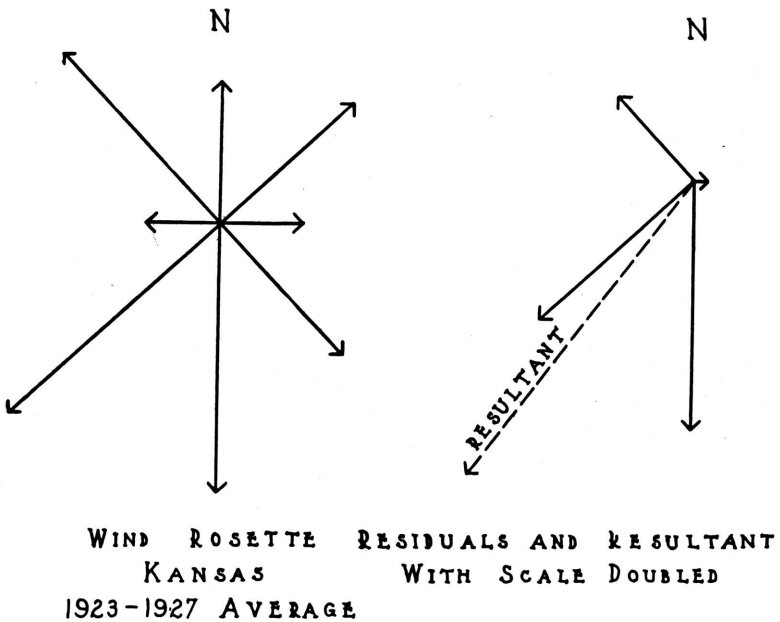



FIGURE 1.

east. However, this line of reasoning is open to objection, for the presence of a continental glacier to the north may have altered the prevailing wind direction in early Pleistocene times.

One would expect the variation in thickness of the deposits in a given direction to be a clue as to the direction from which the ash came. It was undoubtedly true immediately after the eruption that the ash decreased in thickness from the source outward. However, with the reworking of the ash this difference was largely obliterated, and the thicker ash deposits of to-day signify deeper depositories rather than closer proximity to the source. Of course there is a limit to this, for beyond a certain distance from the volcano there

will be insufficient material to make an excessively deep deposit, regardless of the depth of the depression.

Ash deposits of early Pleistocene age must have come from a volcano which was in eruption during that period. In the intervening time between then and now a volcanic cone would suffer but little erosion. Such eroded plugs as the Spanish Peaks in Colorado and Mount Taylor in New Mexico are too old to be considered. But there are in New Mexico a number of volcanoes of post-Tertiary age. One of these or a group of these probably produced the volcanic ash of the Great Plains area.

The writer suggests the Capulin group of volcanoes, near the northeastern corner of New Mexico, as the most probable source for this ash. These volcanoes[14] are post-Tertiary in age and lie to the southwest of the ash-covered area very near its point of convergence. The principal volcano of the group is Mount Capulin, 6 miles south of the town of Folsom. This mountain rises about 1,500 feet above the plains and has a diameter at the base of 1½ miles with a crater 1,500 feet in diameter and 75 to 275 feet deep. To the north and south of Capulin are a dozen or more similar cones which were eruptive during the same general period. This group most closely fits the conditions required of the volcanoes that produced the Pleistocene ash found in Kansas and adjacent states.[15]

## DISTRIBUTION BY COUNTIES.

### Comanche County.

The only deposit of volcanic ash known in Comanche county is in the northern part about 1 mile north of the town of Wilmore. Here about 6 feet of ash crops out along the side of a hill in a pasture. What is probably the same deposit is exposed about 200 feet eastward on the west side of a small valley. One to 2 feet of soil overburden covers the deposit, while the lower contact is not exposed. The ash is extremely cross-bedded. It is greyish white in color and contains a few medium-sized lumps. The following textural analysis shows it to be of medium fineness:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 1% | 27% | 39% | 19% | 14% | 133 | 27 |

14. Lee, Willis T. Extinct Volcanoes of Northeast New Mexico: American Forestry, vol. 18, 357-365, 1912. Charles Keyes (Pan-American Geologist: 38, p. 413, 1922) has also suggested Mount Capulin as a possible source for the Great Plains ash, but he believes the volcano to be too recent. The writer admits that the last activity of this cone may have been very recent, but the ash was blown out during an earlier eruptive stage.

15. For a more complete discussion of the source of the Pleistocene ash the reader is referred to a paper by the writer to be published in the Bulletin of the Geological Society of America.

This deposit has not yet been opened up. It is not of a great size, but because of the short haul to the railroad at Wilmore it holds promise of eventually being developed.

### Decatur County.

Two deposits of volcanic ash are reported from Decatur county. One of these is on the Lem Gillette farm southwest of Oberlin, in the southwest quarter of sec. 8, T. 4 S., R. 29 W. This ash is very definitely of Tertiary age. It crops out in several places along a northward-sloping draw and its tributaries and is in every instance lying under a "mortar bed." The ash is light bluish gray in color and very compact. Because of the superior hardness of the overburden the latter slightly overhangs the outcropping ash. About 4 feet of ash is exposed. In spite of its compact character it was readily broken down and proved to have an unusually high percentage capable of passing through the 200- and 300-mesh screens. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index | Rank. |
|---|---|---|---|---|---|---|
| 0.6% | 13% | 23% | 35% | 28% | 205 | 7 |

However, it is doubtful if this ash could ever be considered a commercial proposition, due to the presence of the overlying rock.

A similar deposit is reported to occur in section 12 of the next township to the west on the farm of Hjalmer Alstron. This was not visited by the writer.

### Ellsworth County.

There are at least two deposits of volcanic ash known to occur in Ellsworth county. One of these is located 2 to 3 miles east of Kanopolis, adjoining the Union Pacific right of way. This was not visited by the writer. The other deposit is located on the Hudson place, about 2 miles east and 7 miles south of Kanopolis. The ash crops out at the top of a high bluff on the southeast side of a northeastward-flowing stream. The outcrop is 100 feet long with a maximum thickness of 13 feet. This prominent exposure of dazzling white ash is easily visible from points some distance westward and northward. However, it is believed that in spite of the large outcrop the tonnage is not great, for ash does not appear across the ridge a short distance eastward. The overburden varies from nothing to 2 feet and consists of soil with a few pebbles. The upper 3 feet of ash contains a number of clay partings, but the next 4 feet is of good grade. The lower portion of the ash bed was covered

by slumped material and could not be tested. The deposit overlies the Dakota sandstone. Because of its white color and unconsolidated condition it is undoubtedly of Pleistocene age.

The sample collected was light gray and very free from lumps. It proved to be of good grade texturally, for over half passed through the 200-mesh screen, and 13 per cent was finer than 300-mesh. The screen analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.1% | 7% | 41% | 39% | 13% | 171 | 13 |

Due to its distance from the railroad and probable small size, a profitable exploitation of this ash is questionable. However, the deposit is under lease and the attempt may be made to market the material.

### Gove County.

The only known deposit in Gove county is located about 10 miles southwest of Quinter in the northeast quarter of the southwest quarter of sec. 21, T. 13 S., R. 26 W. It occurs on the east side of a southward-flowing tributary of Hackberry creek. The ash forms a glistening white bluff for a short distance, overlying the Smoky Hill chalk formation. The maximum thickness exposed is 14 feet with an overburden of soil and pebbles varying in thickness from 1 to 5 feet. The deposit is claimed to increase in depth back into the hill to the eastward. The bottom four feet of the exposed ash is gray in color and feels clayey. About midway between the top and bottom contact are a number of discoidal concretions.

The ash above the clayey lower portion is grayish white in color and fairly free from lumps. The screen analysis of this material follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.5% | 2% | 26% | 40% | 32% | 233 | 6 |

The ash is unusually fine, with 72 per cent passing through the 200-mesh screen. Although by no means of the same quality, the lowermost 4 feet of ash is still of better textural grade than many other deposits. Its analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index |
|---|---|---|---|---|---|
| 0.1% | 3% | 34% | 53% | 10% | 180 |

It would be quite possible to mine and market this lowermost 4 feet along with the other material.

It has been estimated that this deposit contains 60,000 tons of

volcanic ash. The maximum thickness is reported to be 16 feet, but this dimension tapers to the north and south. About fifteen years ago this property was opened up and seven cars were shipped. It is now inactive, however, and will doubtless remain so until other Kansas deposits closer to transportation facilities are exhausted.

### Graham County.

Only one deposit is known in Graham county. This is situated in the western part of the county 1½ miles north of the west edge of the town of Morland. It is owned by M. L. Mitchell, of Tulsa, Okla. The ash crops out on the north side of a large draw and on the western side of a tributary draw. Volcanic ash thrown out by a gopher was also found on the east side of the tributary draw. The size of the deposit is not known, but it is probably not very great. The outcrop is 40 feet wide and the maximum height 9 feet. Both the depth into the hill and the lateral extent beyond the gopher hole across the tributary draw are unknown. The ash grades into loess at the sides and on the top. A thin veneer of gravel covers the deposit.

The ash itself is of exceptionally fine quality. It is grayish white in color and contains no lumps. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.4% | 2% | 12% | 36% | 50% | 283 | 2 |

This is next to the finest of the ash deposits examined, with 50 per cent passing through the 300-mesh screen. Because of its quality and the short haul necessary to the railroad at Morland this deposit is well worth prospecting to determine if its size is sufficient to warrant exploitation.

### Grant County.

There are at least four deposits of volcanic ash in Grant county, but only two of these were visited by the writer. They are all located in the southeast corner of the county in T. 30 S., R. 35 W. The nearest town is Satanta, which lies a few miles east in Haskell county. Only one of these deposits has been opened commercially. This is known variously as the Western Spar Products Company and the Dodge City Spar Company mine in the northwest quarter of section 24. This mine was formerly connected with the Santa Fe railroad by a narrow-gauge spur running north from what is known as Spar Siding. The tracks have been recently pulled up. The deposit lies on the north side of a large valley. It averages 9 feet

thick with an overburden of 1 to 4 feet. The latter consists of loess and sand with occasional lime pebbles. Some of the ash may have been water-lain, but most of it is in wind-blown dunes as is the sand overburden. The ash is of exceptional quality. It is gray and free from lumps. The screen analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.2% | 5% | 18% | 25% | 52% | 276 | 3 |

Although not at present in operation, this deposit has produced several thousand tons, while the remaining ash has been estimated at about 15,000 tons. The workings consist of a large pit covering several acres. It is reported that the company had a mill in Dodge City, which was condemned on account of the dust produced.

Another deposit occurs three-tenths of a mile east. It is opened up by a shallow pit about 15 feet wide and 20 feet long. The overburden is 4 feet. This may be the deposit owned by the Pumicite Company, and reported to contain 60,000 tons of ash. To the northwest, in the northwest quarter of section 17, is a deposit owned by C. D. Hickok, of Ulysses, Kan. The owner's description follows: "I do not know how large in area or depth this deposit is, but I estimate that it covers about 80 acres and that it may have a depth of from 8 to 14 feet." In the northwest corner of the township, in the north half of the southwest quarter of section 6, is a deposit of unknown size. It is owned by Charles P. Metcalf, of Lawrence, Kan. Discovery was made by means of ash thrown out of a badger hole. Neither of the last two deposits was visited by the writer.

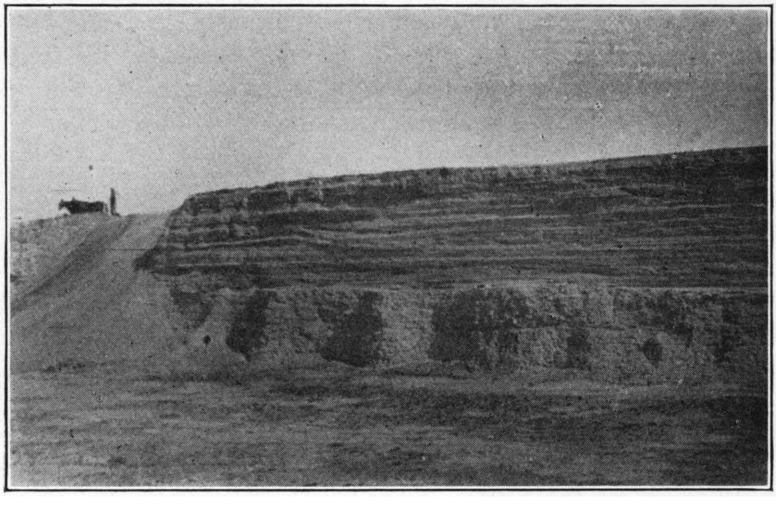
### Hamilton County.

N. W. Bass[16] has described the following occurrences of volcanic ash in southern Hamilton county: "A bed 1½ feet thick occurs near the east quarter corner of sec. 20, T. 26 S., R. 41 W. It is at least 1½ feet thick in the southwest quarter of the southwest quarter, sec. 22, and 2½ feet thick near the center of sec. 13, T. 26 S., R. 41 W., where it is extensively exposed. Other exposures occur in the southeast quarter of the southeast quarter of sec. 1, T. 26 S., R. 42 W.; southwest quarter of sec. 28; the southeast quarter of sec. 14, T. 26 S., R. 41 W., and the northeast quarter of sec. 29, T. 26 S., R. 40 W." The largest one of these, the one occurring in sec. 13, T. 26 S., R. 41 W., was visited by the writer. It consists

16. Bulletin 11, State Geological Survey of Kansas, page 82.

of a massive ledge of compact white volcanic ash. The exposure on the side of the draw is about 70 feet long and about 2½ feet thick. The ash runs back into the hill under overburden consisting

A.—Volcanic ash in Western Spar Products mine, southeastern Grant county.



B.—Volcanic ash and overburden, Cudahy mine, Meade county.

PLATE II.

of soil and quartz pebbles. Soil likewise underlies the volcanic ash bed for a distance of about 2 feet where appears the top of the Dakota sandstone.

Because of its white color and associations this ash is probably of Pleistocene age. However, it differs from most of the other Pleistocene ash deposits in that the material is very compact and breaks off into slabby layers. The conclusion is that it was deposited in water. A shallow lake at one time existed here, into which ash both fell from the air and was blown from the surrounding land. The water settling made a much more compact deposit than is usually the case.

Because of its lumpy character the samples collected from Hamilton county had to be crushed before screening. The material proved to be the coarsest studied, giving an index number of 61. Only 9 per cent went through the 200-mesh screen and only 2 per cent through the 300-mesh screen. The complete analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 13% | 39% | 39% | 7% | 2% | 61 | 37 |

Due to the compact condition of the ash, the small size of the deposit and its inaccessibility in regard to railroad transportation neither this deposit or any others so far found in Hamilton county can be considered as having commercial possibilities.

## Harper County.

There are two known deposits of volcanic ash in this county. Both occur about 2 miles east of Anthony. The larger one is owned by the Pumicite Company. It is located a short distance south of state highway No. 44 and north of the Kiowa-Hartner branch of the Missouri Pacific railroad, with which a short spur connects. The deposit is basin-shaped with the maximum thickness 6 feet. The overburden is 2 to 3 feet thick and consists of red soil with a scattering of pebbles. The bottom of the deposit is marked by a zone of concretions. The ash is yellow in color and lumpy. Impurities present are iron, clay, and calcium carbonate. All three of these substances may act as binders, producing the lumpy condition. The sample collected by the writer gave an extremely poor screen analysis, with only 2 per cent passing through the 300-mesh screen. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 3.5% | 42% | 41% | 12% | 2% | 73 | 36 |

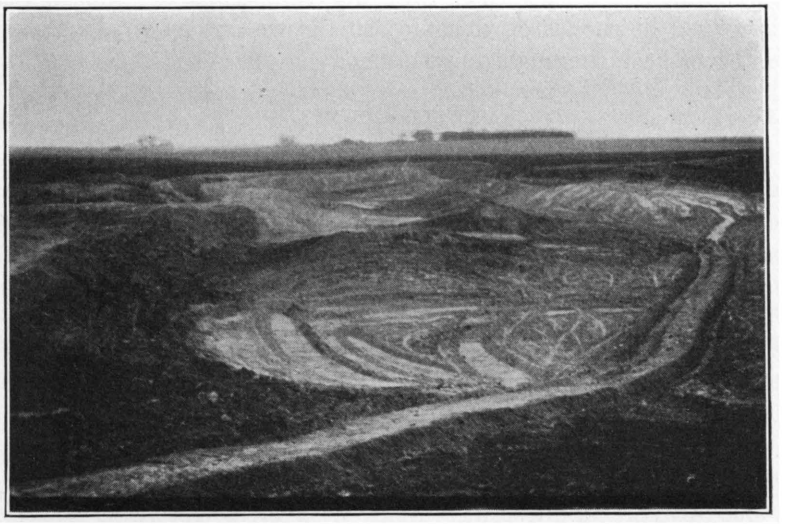
The material caught on the 100-mesh screen consisted of many small aggregates which when broken down by proper milling would increase the percentages of finer ash. This was the poorest commercial ash analyzed by the writer, but he has been informed that since his visit to the deposit a better grade of material has been uncovered.

This deposit was opened up in 1926 and produced a small tonnage during that year. The overburden is scooped to one side and the ash picked up by two wheeler scrapers pulled by tractors. Additional equipment includes a suction fan mounted on a wagon and operated by a Ford engine which sucks up the dry ash. This has not proven very successful. The wheeler scrapers are pulled to the near-by mill and the ash dumped into a bin. A traveling link chain picks up the ash from the bottom of the converging sides of the bin and delivers it to another chain which carries it to the top of the mill. The reputed capacity of the mill is two tons an hour. In the summer of 1927 twelve men were employed on the property. The ash is dried by passing it through a rotating cylindrical dryer. This machine burns oil, and is inclined at such an angle that the ash works down from the upper to the lower end as it is being dried. When the mill was visited by the writer the ash from the drier was elevated to the top of the mill and blown out over a series of bins by a draft of air. The coarsest material fell first and was rejected. Following the reject bin there were three bins which collected successively finer material. The contents of these bins were marketed as different grades. Some of the ash was sacked in 40-pound paper bags, and the remainder went into 100-pound burlap bags with paper liners. Because of the spur it is possible to load directly from the mill into the car. One car holds from 1,500 to 3,000 of the 40-pound bags. The air separation was not completely successful so it has been abandoned and mechanical screens are now used instead.

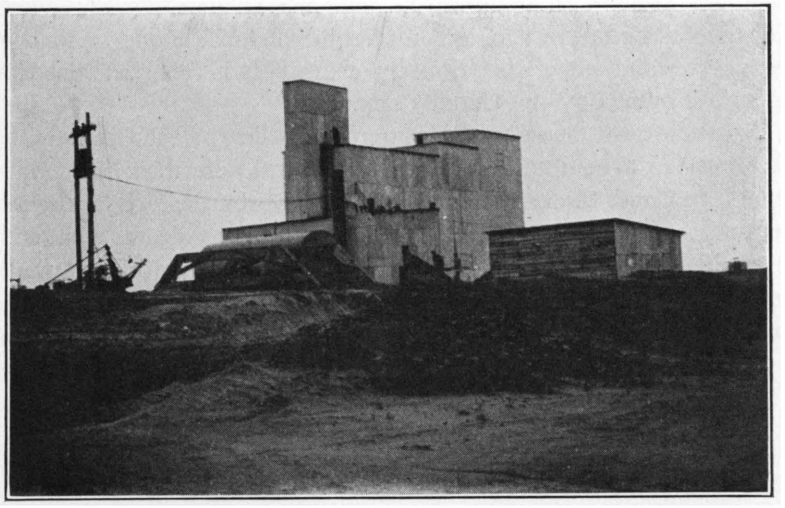
The second deposit is very much smaller and lies a few feet east of the Pumicite Company property on both sides of the highway. It has not yet been opened up commercially. Both of these deposits are of Pleistocene age.

### Haskell County.

Only one deposit has been reported from this county and that was not visited by the writer. It is owned by F. E. Murphy, of Sublette, and is located in the southeast quarter of sec. 19, T. 30 S., R. 34 W. This is in the southwest corner of the county, and it is



A.—Strip pit in volcanic ash near Anthony, Kan.



B.—Mill of Pumicite Company, Anthony, Kan.

PLATE III.

but a short distance westward to the Western Spar Products Company mine in southeastern Grant county. The Murphy deposit was discovered by means of volcanic ash thrown out by a gopher. It has never been thoroughly prospected.

### Jewell County.

The Pumicite Company has record of about thirty deposits of volcanic ash in Jewell county. Although none of these are as yet developed the total tonnage probably lies between three and four million. The deposits visited by the writer were located 3 miles north and from 1½ to 3½ miles west of the town of Burr Oak. They will be described from east to west. On the north side of the section line road, 3 miles north and a little over a mile west of Burr Oak, a large deposit crops out in a cornfield. From the patches of white visible here and there it is obvious that the deposit must cover a good many acres. In one place the plow has thrown out several pure chunks of grayish white ash. A textural analysis of this material follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.08% | 16% | 37% | 35% | 12% | 155 | 18 |

The thickness of the deposit at this point is unknown, but it must be at least 5 feet. The overburden consists of soil which ranges in thickness from nothing upward. The major slope is southward. Volcanic ash crops out for a considerable distance along this slope, weaving in and out of the tributary draws. It is reported that this deposit is owned by the Cudahy company.

Proceeding to the westward ash crops out in the road two-tenths and four-tenths of a mile from the deposit just described. Here it is from 5 to 6 feet thick with loess and soil overburden. Beneath the deposit crops out the Smoky Hill chalk. The volcanic ash outcrops lie on opposite sides of a small southward draining stream valley. The western one was sampled. Although white in color and free from lumps it was not as good quality texturally as the very incomplete sample taken from the cornfield deposit to the east. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.18% | 29% | 38% | 27% | 6% | 116 | 29 |

About a mile farther westward and north of the road on the Soliday place, is a deposit about 12 feet thick. The ash is exposed in a vertical face on the west side of a small valley. At the top is a considerable thickness of clay and soil. Next comes 4 feet of brown ash

followed by 7½ feet of white ash. The bottom contact was obscured by slumped material. The white ash was very prettily cross-bedded. A sample was taken of the brown ash to determine if it likewise had commercial value. Although lumpy and containing a small amount of calcium carbonate this material proved to be unusually fine. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.45% | 25% | 27% | 24% | 24% | 171 | 13 |

None of the Jewell county deposits were operating or had been operated at the time of the writer's visit. However, it was reported that most of the deposits were either owned by Cudahy or under lease by the Pumicite Company and that active development would start within a short time. Because of the huge tonnage in this vicinity and the good quality of the ash these deposits are well worth opening up. The nearest railroad is at Burr Oak, about 4 miles distant.

### Lane County.

Mr. H. T. Martin has reported the presence of deposits of volcanic ash in northeastern Lane county. These were not visited by the writer.

### Lincoln County.

A deposit in the southwest corner of this county has been reported by the owner, Ernest A. Hanzlicek, of Wilson, Kan. It is situated in sec. 27, T. 13 S., R. 10 W. He states that the thickness varies from 3 to 12 feet, and the areal extent is unknown. The sample sent into this office was gray in color with a few lumps containing calcium carbonate cement. The textural analysis shows it to be of medium quality. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.6% | 15% | 41% | 29% | 14% | 155 | 18 |

### Logan County.

One deposit of volcanic ash is known to occur in Logan county. This is situated in T. 14 S., R. 33 W., about 1½ miles north of the Smoky Hill river and 2 miles east of bridge. This neighborhood is very thinly settled and the nearest railroad is about 20 miles to the north. The deposit crops out in a bank on the east side of a draw which carries a minor tributary of the Smoky Hill. The outcrop can be traced for about 250 feet. The ash is from 5 to 6 feet thick

and the overburden varies from 1 to 4 feet. The latter consists of loess topped by a pebble zone. Immediately beneath the bottom contact of the deposit occur buff-colored beds of the Smoky Hill chalk formation. Within the ash are a large number of concretions, which under the microscope are seen to consist of ash and feldspar mosaic with calcite cement. The feldspar crystals are about the same size as the glass particles, but are granular, whereas the latter tend to an elongate form. About midway between the top and the bottom of the outcrop there occurs a 6-inch zone of relatively coarse ash. For a few inches above this zone the ash is stained a buff color.

The bulk of the ash is gray and fairly free from lumps. The textural analysis shows it to be of medium grade, with 45 per cent passing through the 200-mesh screen, but only 5 per cent passing through the 300-mesh. The complete analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 2.5% | 16% | 37% | 40% | 5% | 137 | 25 |

This deposit has never been commercially developed, and owing to its inaccessibility it is doubtful if it will be exploited for some time. Another deposit has been reported in this locality south of the Smoky Hill river, but it could not be found.

## McPherson County.

A number of deposits are found in north-central McPherson county, but most of them are very small. Probably the largest one is located on the farm of C. P. Larson, in the northwest quarter of sec. 20, T. 18 S., R. 3 W. The Union Pacific railroad running between McPherson and Lindsborg passes within a few feet of the deposit, but the nearest spur is at Johnstown, a little over a mile north. The deposit occurs on the west side of a northward-sloping draw. It extends across the divide between two tributary draws, but has been eroded away from the bottom. The owner has found ash by drill over 5 or 6 acres, with an average thickness of 6 feet and a maximum thickness of 9 feet. He calculates that he has 8,000 tons per acre. The overburden varies from 6 inches to 9 feet, and even greater under the hill to the west. It consists of soil and contains no gravel.

The ash proved to be of a fair quality. It is a light gray color with no lumps. The screen analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.1% | 30% | 1% | 52% | 17% | 173 | 12 |

A small pit marks the place where one carload (about 55 tons) of ash was removed and shipped two years ago. Due to the proximity of this deposit to the railroad and industrial centers its development should be a profitable venture. However, at the present time unfavorable freight rates prevent the starting of operations.

A small deposit is reported to occur 1 mile north and 3 miles east of the C. P. Larson property, on Kentucky creek. This locality was not visited. South of the Larson farm on the north side of section 29, in the same township, volcanic ash crops out in the road just west of the Meridian highway (federal highway No. 81). The railroad lies across the divide to the west, and the farm of Fred Vogel, into which the deposit runs, adjoins the road to the south. About 3 feet of ash is exposed in the road. The overburden consists of soil with lime concretions, while the ash is compact and slabby. It may have been deposited in water like the ash of Hamilton county. A sample was taken and tested which ran slightly better than that secured from the large deposit to the north. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.8% | 11% | 31% | 33% | 24% | 193 | 9 |

The size of this deposit is entirely unknown. Due to its location and the quality of the ash it at least should merit prospecting.

Another deposit was found farther west on the farm of Gus Larson. This is located in the southwest corner of sec. 15, T. 18 S., R. 4 W. In this vicinity the ash crops out in a stream bed and in a near-by road cut and cornfield. The areal extent is unknown, but the tonnage cannot be great because the thickness is not over 3 feet. The stream-bed outcrop was very interesting because it showed ash associated with the McPherson formation, a Pleistocene river deposit. Immediately above sands of the McPherson formation occurred 10 inches of yellow and brown ash, of which the bottom part appeared to have been water-laid. Then came 2 feet of white wind-blown ash followed by 3 inches of impure water-laid ash and 1 foot or more of soil. This occurrence proves that the white ash is above and younger than part, at least, of the McPherson formation. The presence of water-laid ash above the wind-blown ash may indicate that the eruption took place before the deposition of the McPherson formation was entirely complete.

The ash from this vicinity was of a lower grade than that from the other deposits of McPherson county. However, it is in no sense

of the word a coarse ash, but one of average fineness. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.2% | 23% | 31% | 27% | 19% | 161 | 16 |

Considerable calcium carbonate makes the ash lumpy and a slight amount of iron discolors it yellow. This deposit does not hold much promise for development in the near future, because of its relatively small size and distance from the railroad.

## Meade County.

Meade county contains an abundance of volcanic ash occurring in at least twelve separate deposits. The largest of these is in the northern part of the county, 7½ miles west of Fowler. Several deposits are found west and south of Meade, in the central part of the county, while a single deposit is located close to the town of Fowler.

The large deposit west of Fowler is owned by the Cudahy Packing Company and is an important source of Old Dutch Cleanser. The company has erected a mill on the property, which is connected by a spur of the Rock Island railroad extending from Fowler. The deposit is on the south side of a large draw. It contains a tonnage variously estimated between one million and one and one-half million tons. It merges upward into a sand and soil overburden which is around 15 feet in thickness. The average thickness of the ash bed is 16 feet with a maximum of 20 feet. A few concretions are found in a zone at the bottom of the deposit.

The ash is grayish white and contains a few lumps which usually break down readily into fine ash. In texture the material is of medium quality. The screen analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.1% | 18% | 42% | 27% | 13% | 148 | 20 |

Under the microscope the ash is seen to consist of about 90 per cent natural glass fragments and about 10 per cent feldspar crystals. These latter are very fresh. The deposit is of Pleistocene age.

At this mine the ash is shoveled by hand from the quarry floor into wagons which carry it to the mill and dump it into a hopper. From there it is carried into an inclined oil-burning rotary kiln where the moisture is driven out. This amounts to about 20 per cent of the total. Next the ash passes through a revolving screen of about five mesh and then through an air separator into a paper-

lined freight car. The oversize picked out by the revolving screen and the overweight material secured from the air separator constitute waste and are rejected. The ash is shipped to Chicago, where 2 per cent soap compound is added and the material marketed. This plant has only been in operation for about two years, but the deposit has been worked for over thirteen years. The maximum capacity is 10 tons per hour or 20 to 25 cars per week. The annual production is around thirty thousand tons a year. About twenty-five men are employed. At the present rate of production the deposit will last for a long time, for only 60 acres have so far been stripped, and the deposit is reputed to cover 400 acres. One mile south the same company owns other deposits with an estimated tonnage of about 100,000 tons. The Pumicite Company owns a deposit ¼ mile north which contains a smaller amount of ash.

A deposit owned by the Pumicite Company and Robert Ingram, of Fowler, lies 1 mile east and ¼ mile north of that town. Also to the north and west there are reported to be one or two other deposits which are leased by Mr. Ingram. The deposit visited by the writer covers a small area, but is thick. It underlies the Rock Island railroad track and federal highway No. 54 at and adjacent to their crossing. Eighteen feet of ash with 3 to 8 feet of overburden are exposed. The maximum thickness of ash is claimed to be 20 feet. It merges into the overburden, which consists of soil or loess covered by sand.

The ash is very similar in its properties and texture to that mined by Cudahy. Like the other deposits in Meade county, it is Pleistocene in age and quite unconsolidated. Screen analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.1% | 24% | 41% | 20% | 15% | 141 | 23 |

The very small percentage caught on the 20-mesh screen consisted of small ash aggregates and quartz grains and pebbles which evidently worked down from the overburden.

The deposit has been opened up in a small way. In 1926 about 700 tons were mined and hauled to Fowler for shipment, and shipments were also made in the two preceding years. It was supposed to have contained about 12,000 tons originally. There are two pits for wagon hauling, one on either side of the railroad track adjacent to the right of way.

About 1½ miles west of the town of Meade and south of the highway is a deposit leased by the National Silica Manufacturing

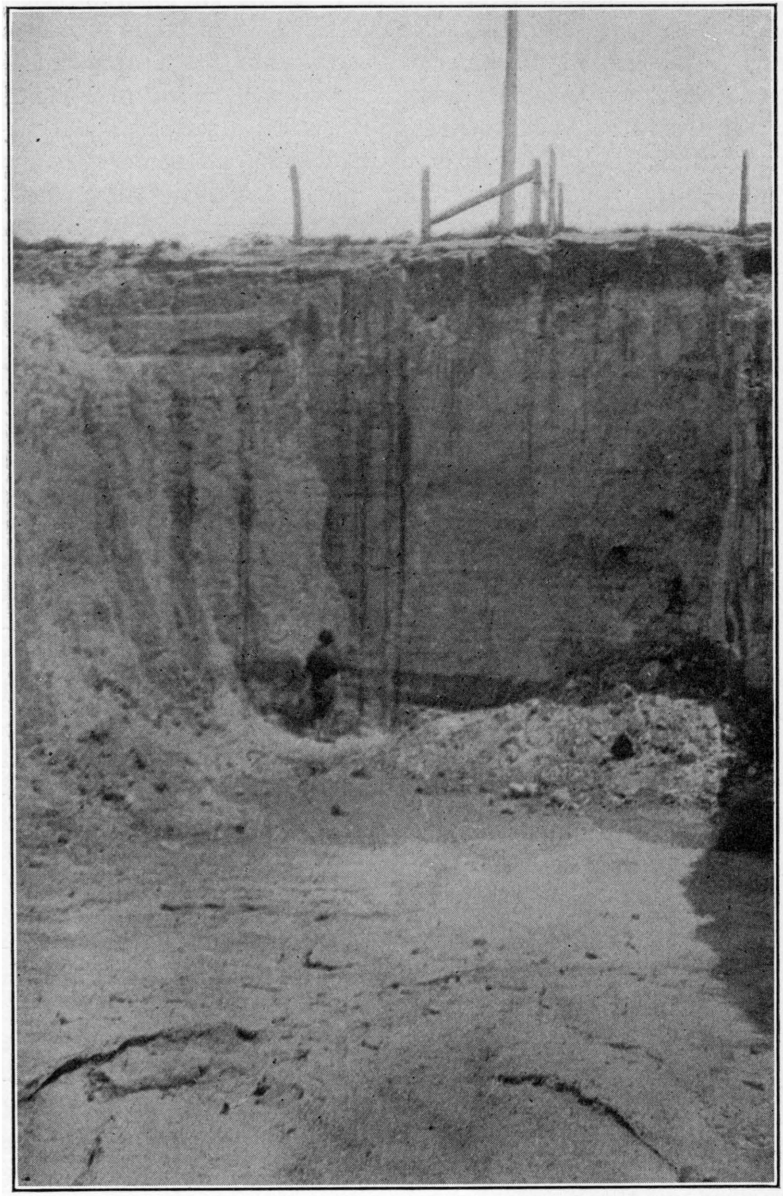


PLATE IV.—Twenty-foot ash bed near Fowler, Meade county.

Company and owned by the Puck Soap Company, of Des Moines, Iowa. Estimates of the tonnage vary greatly. Unlike the Cudahy property, this deposit lies on a southward-facing slope. It consists of 17 feet of ash with 10 feet of overburden consisting of brown sandy clay with a few pebbles. The ash is similar in appearance to that found in the other deposits of Meade county, but it ranks a little higher texturally. The screen analysis is given below:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 1% | 22% | 34% | 22% | 21% | 162 | 15 |

The company owns its own spur, which parallels the railroad track a short distance north of the deposit. A mill containing a dryer with a screen classifier was burned three years ago. Since that date shipments have been made of crude ash only and these have been small and sporadic.

There are a number of other deposits in the vicinity of Meade, but none of them were visited by the writer. The Pumicite Company has bought property adjoining the National Silica Manufacturing Company lease. The latter company has an option on property to the west. About 4 and 5 miles south of Meade are the McSherry and the Myers properties. These have never been opened up, but are thought to be medium-sized deposits, and with an increased demand for volcanic ash will probably be developed.

### Morton County.

A number of bulletins on mineral resources of the United States Geological Survey mention the occurrence of volcanic ash in Morton county. However, the writer could find no trace of any deposit in this county, and officials of the Santa Fe railroad reported no shipments of volcanic ash. Probably a typographical error was made and the county should have read Norton.

### Nemaha County.

The easternmost deposit of volcanic ash known to occur in Kansas is found in T. 4 S., R. 11 E., Nemaha county. It is found on the J. W. Shell farm, 1½ miles east of Vermillion and but a few feet east of the Marshall county line, and a few feet south of state highway No. 9. The owner has dug a very small pit in his cornfield into the ash. The deposit is from 1 to 1½ feet thick with an overburden of 1 foot and more. The ash is yellowish white in color and appears to be clayey and impure. This is to be expected because

ash traveling such a great distance must have been considerably reworked with a consequent mixing in of foreign materials. However, it is free from lumps and of fair textural quality. It would have to be fairly fine to have been carried by the wind for this great distance. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 1.5% | 33% | 25% | 24% | 17% | 141 | 23 |

A short distance northwest, in a road cut on the south side of highway No. 9 and very close to the Marshall county line, occurs another outcrop of volcanic ash which may be a part of the same deposit. The material was brown in color and lumpy. Both deposits are found on the east facing flank of a tributary valley. The small tonnage of ash found in this locality precludes the possibility of any large-scale production.

## Ness County.

A small deposit of volcanic ash occurs in the northwest corner of Ness City. It lies just north of a curving wagon road on the point between a small stream and its tributary. The ash is exposed in a cave. The thickness is about 2 feet and the lateral extent unknown, but it is probably slight. The overburden consists of soil and pebbles and is from 3 to 4 feet in thickness. Due to the fact that this deposit was not opened up a good sample could not be secured. The ash collected was brownish gray in color and very lumpy. An acid test showed the presence of calcium carbonate. The screen analysis proved it to be very poor ash with a rank of 31. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 22% | 23% | 20% | 24% | 11% | 112 | 31 |

Because of its probable small size this deposit cannot be considered of economic importance.

## Norton County.

Norton county has been a producer of volcanic ash for a good many years. So far production has been confined to deposits in the vicinity of Calvert, lying a few miles east of the town of Norton. Other deposits are known not only in this vicinity but also south and west of Norton, especially in the vicinity of Dellvale. Over twenty deposits in all have been found. Unlike most of the Kansas ash, which is white or gray in color, the Norton ash is light bluish gray

and more compact than is the usual white ash. It is often found under the so-called "mortar beds" of the Ogalalla formation, from which it is assumed that this type of ash is earlier in age and should be classed as Tertiary.

The deposit operated at present is located a short distance southeast of the town of Calvert. At the time of the writer's visit there were three adjoining quarries in the ash, but only the easternmost one was being worked. The westernmost quarry is owned by the J. B. Ford Company, of Wyandotte, Mich. Although now abandoned, this property has produced a very large tonnage. It is reported that concretions 10 to 12 feet across were found while mining this ash. The two eastern quarries are owned by J. A. Miller, of Norton, and have been leased to various operating companies. Many thousands of tons have been removed from these quarries also. It is estimated that the total original tonnage was well over one million tons. The deposit is located on the south flank of Prairie Dog creek valley. The present working face contains from 10 to 11 feet of ash, and the overburden varies from 3 to 10 feet, but will probably increase as the excavation is carried farther southward into the hill. It appeared to be yellow sand, but when examined under the microscope it proved to consist of a number of quartz-sand grains and a multitude of ash particles of varying sizes. These latter were kaolinized and otherwise altered. Probably this overburden is largely a reworked ash deposit to which considerable wind-blown sand has been added.

The ash itself differs from the usual Pleistocene ash in that it is not cross-bedded. All the bands are horizontal and some of the ash is quite compact. Due to these facts it is concluded that at least a portion of this Tertiary ash was water deposited. In the first 5 or 6 feet of the ash were a number of cylindrical concretions locally referred to as "bones." It is reported that some real animal bones were found in this deposit about 6 feet from the top. When examined under the microscope the ash appears to consist of about 10 per cent crystalline material and about 90 per cent rock-glass fragments. The crystalline content was mostly feldspar which was sufficiently kaolinized to impart a yellowish green color to the mass. Although free from lumps the Calvert ash ranks rather low from a textural standpoint, for only 7 per cent passed through the 300-mesh screen. The complete analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.4% | 27% | 44% | 22% | 7% | 116 | 29 |

A study of a thin section made of one of the concretions shows that there is considerable triturated cone material in the ash. Perhaps this will account for the lesser degree of fineness exhibited.

The middle quarry was being stripped on two levels. Ash secured from the upper level was hoppered into a rotating screen where the oversize was caught and removed by an endless belt, while the ash itself passed through into a wagon standing beneath. At the easternmost quarry the same device was used, but as development here was proceeding on one level only the screen was set up on the quarry floor. From the quarry the ash is carried by wagons to Calvert, where loading is accomplished by means of an incline with a hopper at the top. A short spur connects the loader with the Rock Island railroad. A few years ago a mill was erected in Calvert with a revolving tube dryer. However, this was never operated with great success, and all of the ash recently mined has been sold crude. The present production is around eight or ten cars per month, but this amount could be considerably increased should a sufficient demand develop.

Another deposit is reported to be located on the farm of Oscar Mattan, 3 miles east and 1 mile south of the town of Norton. This was not visited by the writer. Ten and eight-tenths miles south of Norton is a third deposit. Outcrops of this ash can easily be discerned on both sides of highway No. 21, on the banks of a southeastward-flowing stream. The thickness varies between 5 and 7 feet, while the overburden ranges from nothing up to 10 feet and over, and consists of impure ash, loess and pebbles. The ash is of Tertiary age. It is finely banded and blue in color. Some of the bands are very wavy, giving a bird's-eye maple appearance. This may be due to deposition in a disturbed body of water which produced ripple marks. Near the bottom the material is very compact. Although much lumpier than at Calvert, the textural quality of this ash is very similar. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 1.8% | 29% | 38% | 21% | 10% | 120 | 28 |

The probable small size of this deposit and its distance from the railroad will undoubtedly prevent its development for some time.

Other deposits are known in western Norton county in the vicinity of Dellvale. One of these is located on the property of Julius Vanneter, 2¼ miles west of Dellvale and ¾ mile south of the Rock Island railroad. This deposit is reported to be 7 feet

thick, covering 5 acres and containing 20,000 tons of material. The ash is exposed in a bank on the east side of a main draw which slopes northward. It is not of extreme fineness, but it is free from lumps. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.4% | 24% | 39% | 26% | 11% | 135 | 26 |

A similar deposit is reported to occur on the farm to the west. Also about 2 miles southwest of Dellvale, on the Dave Brunson place, the Cudahy company has a lease on a deposit which is reported to contain 50,000 tons. There will undoubtedly be active development of these Dellvale ash deposits in the next few years.

There are known to be still other deposits in western Norton county. On the north side of the Norton-Oberlin highway, about 6 miles east of Norcatur, a little over 3 feet of volcanic ash crops out in a creek bank.[17] This ash is also of Tertiary age, as it underlies a 2-foot "mortar bed."

### Phillips County.

There is at least one deposit of volcanic ash in this county. It is located southwest of Speed about ½ mile north of the Rooks county line, on the Beckley farm. The tonnage has been estimated at one-half million. Ash crops out in two large southward draining draws some distance apart. It is obvious that the deposit covers many acres. Furthermore it is reported to extend beneath the surface across the road to the east. The thickness of the deposit is not known, but it must be at least 7 feet, for that much is exposed. The overburden varies from 1 foot upward and consists of soil and pebbles. The ash is grayish white and banded, but when completely dried it becomes white and free from lumps. It is also of unusual quality from a textural standpoint, for 60 per cent passed through the 200-mesh screen. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.1% | 14% | 26% | 33% | 27% | 200 | 8 |

It is reported that this property is under lease by the Pumicite company. Although some distance from transportation, the large size and the textural quality of the deposit may warrant its exploitation in the near future.

Bulletins of the United States Bureau of Mines refer to shipments of ash from Woodruff, in the northern part of Phillips county,

17. N. W. Bass. Field Notes.

very close to the Nebraska line. This part of the county was not visited, and no other data on this locality have been found. It is possible that the ash is actually mined across the Nebraska line, in Harlan county, where there are known to be other large deposits of this material.

### Pratt County.

A sample of volcanic ash collected from the southwest corner of sec. 23, T. 27 S., R. 11 W., Pratt county, Kansas, was sent to the writer by Mr. L. W. Kesler, geologist for the Sinclair Oil and Gas Company. The material was light in color, but so unusually compact that a microscopic examination was necessary to determine definitely that it did consist of ash. The high degree of consolidation was due to the unusual amount of clay which is intimately intermixed. In fact each glass particle is almost completely covered be very fine clay particles. In all probability the volcanic ash was deposited in water at the same time as the clay. It is doubtful if this deposit has commercial possibilities, for before it could be marketed it would have to be ground and the unusual quantity of clay present would lessen the abrasive qualities. In addition it was Mr. Kesler's impression that the deposit was of very small extent and consequently might not be of commercial value even if pure.

### Rawlins County.

Several deposits of volcanic ash occur in Rawlins county, but the only ones known to be of commercial importance lie in the west central part, in the vicinity of Beardsley. One of these is on the Lyman place directly south of Beardsley and about ½ mile south of the air-line highway. The deposit is situated on the south side of a deep draw and is reached by a winding road which curves some distance to the west after leaving the highway. The maximum thickness is 14 feet, while laterally the ash grades into loess. The overburden consists of soil and gravel and ranges in thickness from nothing up to several feet. The ash is white in color and free from lumps. Unlike the deposits of Norton county and south central Rawlins county, this ash is of Pleistocene age. It lies about 15 feet above the "mortar beds." The ash proved to be very fine, with almost 80 per cent passing through the 200-mesh screen. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.3% | 4% | 17% | 40% | 39% | 253 | 4 |

The deposit has been opened by a strip pit 110 feet long, about 50 feet wide, and with a maximum depth of about 14 feet. A small tonnage had been removed, but the deposit was not being operated during July, 1927.

Another commercial ash deposit is found about 2 miles southeast of Beardsley on the Charley Mays place. This deposit has recently been purchased by the Pumicite company. Only about 7 feet of ash was exposed when visited by the writer, but it is claimed that the total thickness is 30 feet. The overburden varies from 6 to 15 feet. The first few feet above the commercial ash contains a mixture of sand and ash. Above this lies loess, soil and gravel. The deposit is of Pleistocene age and the ash is light gray in color and free from lumps. The sample taken from this deposit was the finest of any analyzed. Only 14 per cent failed to pass through the 200-mesh screen, and considerably over half went through the last screen. The complete analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.15% | 3% | 11% | 28% | 58% | 299 | 1 |

The deposit has been opened up by a strip pit about 200 by 75 feet in area. Unfortunately the pit was so dug that it occupies a draw and collects the drainage from a considerable territory. A large tonnage has been removed. Because of the fineness of the ash and the nearness to transportation it is believed both of the deposits near Beardsley are well worth operating. Furthermore, because of the presence of a large amount of very fine ash, the material could be screened and the finest ash marketed separately. It should be possible to secure a sufficiently higher price for this grade to more than pay the milling cost.

There are at least two occurrences of Tertiary ash in Rawlins county. These are found southwest of Atwood. One is on the property of George McDougal, in sec. 4, T. 4 S., R. 34 W. Ash is exposed in a bluff just east of the road on the bank of a creek. This material was gray to brown in color and very compact. Between 4 and 5 feet of it crops out for a lateral distance of about 80 feet. Fifty feet of white clay separates the ash from overlying mortar beds. When crushed and screened the ash proved to be of medium quality. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.2% | 25% | 28% | 34% | 13% | 148 | 20 |

However, because of the thickness and the character of the over-

burden, it is not believed that this deposit has commercial possibilities.

Near by, in section 33, T. 3 S., R. 34 W., on the Charles R. Bird farm, is a similar deposit of Tertiary ash. This material is light blue in color and extremely compact. It is essentially a rock. The ash particles are cemented by calcium carbonate which completely fills the pore spaces throughout the entire mass. When viewed under the microscope the ash is seen to consist of the usual angular rock-glass particles plus a few fragments of feldspar and occasionally some other mineral particles. Beneath and merging into the ash is material of an olive-green color which is locally referred to as "natural lime plaster." Upon drying the color turned to a light yellow. This material has been used as a plaster in dwellings in the vicinity by the mere addition of water. When examined under the microscope it is seen to consist of altered and partially devitrified ash (bentonite?) plus a small amount of calcium carbonate. Why it should behave as a plaster is not known, unless the clay minerals resulting from the alteration of the original material combine chemically with water to form a coherent mass.

## Rooks County.

Two deposits of volcanic ash occur in Rooks county. One is situated in the eastern part south of Woodston and the other is near Webster. The former deposit lies in the northeast quarter of sec. 7, T. 8 S., R. 16 W., about 6¾ miles south of Woodston. The property is owned by W. L. Shepard. The deposit crops out on both sides of a very shallow valley running through the farm, and is reported to underlie about 20 acres. The depth was tested but once, and then 15 feet of ash was found. The overburden consists of soil and pebbles and varies from 1½ to 6 feet in thickness. In one place slabs of white, hard sandstone appeared to overlie the ash. The ash itself is cross-bedded and fairly well consolidated. The age of this material is in doubt. Its color is the same as that of the Pleistocene ash, but its consolidation and associations would make it appear Tertiary.

The deposit was sampled only from the outcrop, so it may not be typical of the whole. The ash was gray and lumpy and unusually coarse, with only 16 per cent passing through the 200-mesh screen. The complete analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.0% | 44% | 40% | 8% | 8% | 88 | 35 |

The owner has stripped off the overburden for a short distance, but has not yet attempted to market the material. The haul from the railroad is considerable, and probably it could not be made to pay while present prices prevail. The deposit does, however, merit a more thorough examination to determine its size.

The deposit in the vicinity of Webster was not visited by the writer. Inquiries were made of Mr. V. Bruton, cashier of the Rooks County State Bank at Woodston, and the following answer was received: "There is a bed of volcanic ash on a hilltop about 1½ miles southeast of Webster, Kan. This bed covers probably about 2 acres of land, and seems to have unlimited depth. The party owning this land, so far as we know, is Mr. Frank Walker, Webster, Kan." No samples were examined from this deposit, so its quality is unknown. Inasmuch as it is about 9 miles to the nearest railroad, it will be some time before this deposit has commercial possibilities.

### Russell County.

One deposit of volcanic ash is known to occur in this county. It has been described by Rubey and Bass in their bulletin on the geology of Russell County.[18] They state: "On the west side of a small valley near the southwest corner of section 19, T. 14 S., R. 13 W., a lenticular bed of volcanic ash more than 5 feet thick is exposed for over 350 feet horizontally in the upper part of the gravel bed near Smoky Hill river. The ash is white to cream colored, and is very thin-bedded. It lies with sharp contact on a bed of chalk pebbles, but its upper limit is obscured. The grains of the ash are extremely small and very angular. Under the microscope they are seen to possess the vitroclastic and cellular texture and the isotropic properties characteristic of volcanic ash." The authors further state that the material is Pleistocene in age.

The sample collected by the writer from this same deposit was gray in color and lumpy. The screen analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 15% | 14% | 30% | 25% | 16% | 144 | 22 |

The deposit has never been opened up for commercial development.

### Seward County.

In east Seward county, 4 miles southwest of the town of Kismet and adjoining the Rock Island railroad, is a deposit owned by Thomas C. Perry known as the Sunflower Mineral Mine. When

18. Bulletin 10, State Geological Survey of Kansas.

visited by the writer in the summer of 1927 this property was not in operation, but it was responsible for considerable production during the year 1926. The deposit lies immediately to the northwest of the railroad right of way and is connected by a short spur. It crops out on the east side of a low hill with a maximum exposed thickness of about 7½ feet. The overburden consists of a very light chocolate-colored lumpy material which when examined under the microscope was found to consist of iron-stained ash with a few quartz grains. A number of bone concretions are present within the white ash. The textural rating is rather low, as only 7 per cent passed through the 300-mesh screen. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 1% | 30% | 40% | 22% | 7% | 105 | 32 |

The deposit is opened up by a strip pit in the side of the hill. The undeveloped ash extends for an unknown distance back into the hill. The total amount has been estimated at 2,000 to 3,000 tons.

## Sheridan County.

There are at least four deposits of volcanic ash in Sheridan county, two in the vicinity of Hoxie and two lying north of Tasco, in the east central part of the county. Both of the Hoxie deposits are owned by the Pumicite Company. One of these is situated 2 miles south of town on the east side of the road. The deposit lies on the northeast side of a small valley. It is at least 7 feet thick with an overburden of 1 to 3 feet consisting of loess with pebble capping. The ash is grayish white and contains a few lumps and bone concretions. The screen analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 2.5% | 39% | 34% | 18% | 7% | 98 | 34 |

When visited in the summer of 1927 this deposit was being stripped in preparation for exploitation.

The second Pumicite Company deposit is on the Milton Cooper farm, 2 miles east and 1 mile north of Hoxie. The ash lies on the east side of a main draw south of a tributary draw. The ash outcrops on the valley side and continues east under the hill with increasing overburden to an unknown distance. The overburden consists of loess, pebbles and soil. The thickness of the deposit is unknown. The sample from which the following screen analysis was made was taken from the surface of the exposed ash:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.4% | 15% | 42% | 29% | 14% | 156 | 17 |

If the sample taken is at all indicative of the deposit as a whole this is a much finer ash than that south of Hoxie. The deposit was being drilled by the Pumicite Company preparatory to mining.

One mile east and ¾ mile north of Tasco station, on the Union Pacific railroad, is a deposit owned by J. C. Blackburn, of Tasco. The deposit is about 4 feet thick with a 2-foot overburden. It is reported to underlie 5 acres. The deposit occurs at the top of a divide between a southward-flowing stream and its tributary. The ash is a pale yellowish white with almost no lumps. It is much finer than either of the Hoxie deposits, with 25 per cent passing through the 300-mesh screen. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.3% | 12% | 34% | 29% | 25% | 192 | 10 |

No production was reported from this deposit in 1926, but shipments were being made at the rate of about one car a week in 1927. The ash is loaded in wagons at the mine and carried to Tasco station, where it is loaded into box cars. From 30 to 55 tons are put in a car. the average being about 45. About 23 cars in all have been taken from this deposit.

West of the Blackburn property and about ½ mile north of Tasco is an outcrop of volcanic ash in a bluff on the east side of a southward-flowing stream on the farm of R. S. Ewer. This ash is gray in color and lumpy. A small amount of calcium carbonate is present, cementing the particles together. Clay is also intimately intermixed with the ash. The screen analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 1.4% | 15% | 14% | 28% | 42% | 238 | 5 |

According to the analysis this ash is unusually fine, but its value may be somewhat diminished because of the impurities (clay and calcium carbonate) present. The deposit has never been commercially developed.

## Sherman County.

The presence of volcanic ash on the south bank of the Smoky Hill river in southeastern Sherman county has been reported by Mr. H. T. Martin. This deposit was not found by the writer.

### Smith County.

One deposit of volcanic ash is known in Smith county. This is located 2 miles west of the town of Kensington just east of the Phillips county line and south of federal highway No. 36. The owner is Bert N. Barron. Ash crops out for a short distance along a steep bank on the south side of West Cedar creek. According to the owner the deposit is lens-shaped with a maximum thickness of 22 feet. He states that he has tested the deposit south from the outcrop for a distance of 60 feet. The lateral extent along the creek bank is about 200 feet. The overburden consists of loess and soil with a depth of 1 foot and upwards. The ash is light gray in color and free of lumps. Only 5 per cent passed through the 300-mesh screen, which is unusual for a deposit at such a distance from the probable source. The complete analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.3% | 30% | 45% | 20% | 5% | 105 | 32 |

No attempt has been made as yet to market this ash. The tracks of the Rock Island railroad are within a half mile. Should exploratory work prove the deposit to have considerable tonnage it could probably be worked successfully.

### Stafford County.

A report was made to the State Geological Survey of a deposit of volcanic ash located in southeastern Stafford county by J. G. Tubbs, of Turon, Kan., the owner. The property lies 1 mile north of the Pratt county line and 3 miles west of the Reno county line, in sec. 28, T. 25 S., R. 11 W. The sample submitted was slightly yellowish gray in color, but free from lumps. It proved to be of very good textural quality. The analysis follows:

| Over 20 mesh. | 20 to 100 mesh. | 100 to 200 mesh. | 200 to 300 mesh. | Under 300 mesh. | Index. | Rank. |
|---|---|---|---|---|---|---|
| 0.1% | 8% | 28% | 48% | 16% | 188 | 11 |

### Wallace County.

Mr. Mentor Etnyre, of Goodland, Kan., has reported the presence of two deposits of volcanic ash in northwestern Wallace county. One of these is located in the southeastern corner of T. 11 S., R. 42 W., and the other is in the southwestern part of T. 12 S., R. 41 W. Neither of these was visited by the writer.

## TECHNOLOGY AND USES.

### Prospecting.

Because of the extreme inconsistency of thickness of the average volcanic ash deposit it is essential that every deposit be thoroughly prospected before making an estimate of the tonnage. A surface measurement of the area covered, coupled with the thickness secured from one drill hole, will produce an estimate but little better than a guess. The prospecting method employed by the Pumicite Company, of St. Louis, results in a reasonably accurate estimate, and its use is recommended. The area thought to be underlain by ash is laid off in 50-foot squares and the corners are drilled by means of extension hand augers. This method, although tedious, gives the exact areal dimensions of the deposit, the thickness of the overburden over all parts of the ash bed, and the average thickness and quality of the ash itself. From these data the tonnage of overburden and ash can readily be figured.

### Mining.

Open-cut mining or "stripping" is the only method used in mining volcanic ash. Due to the high cost of operation and the low market value of the product underground methods are not feasible. In stripping two operations are necessary. First the overburden of soil or gravel must be removed. This is usually done by scrapers. The removed material is at first dumped on barren ground, but it may later be discarded into worked-out and abandoned pits. The ash itself is removed in the same manner or by shoveling directly from the pit floor into wagons. In a few instances the material is loaded from the wagon into the car without any intermediate steps. At most localities, however, the presence of hard lumps or concretions necessitates a crude screening on the pit floor. The ash is carried by wagon or scraper to a large mesh screen or grizzly usually located at the top of an incline. Here the material is dumped and the undersize is caught in a wagon beneath. If the ash is to be milled this step is omitted and the material is dumped into a hopper at the mill.

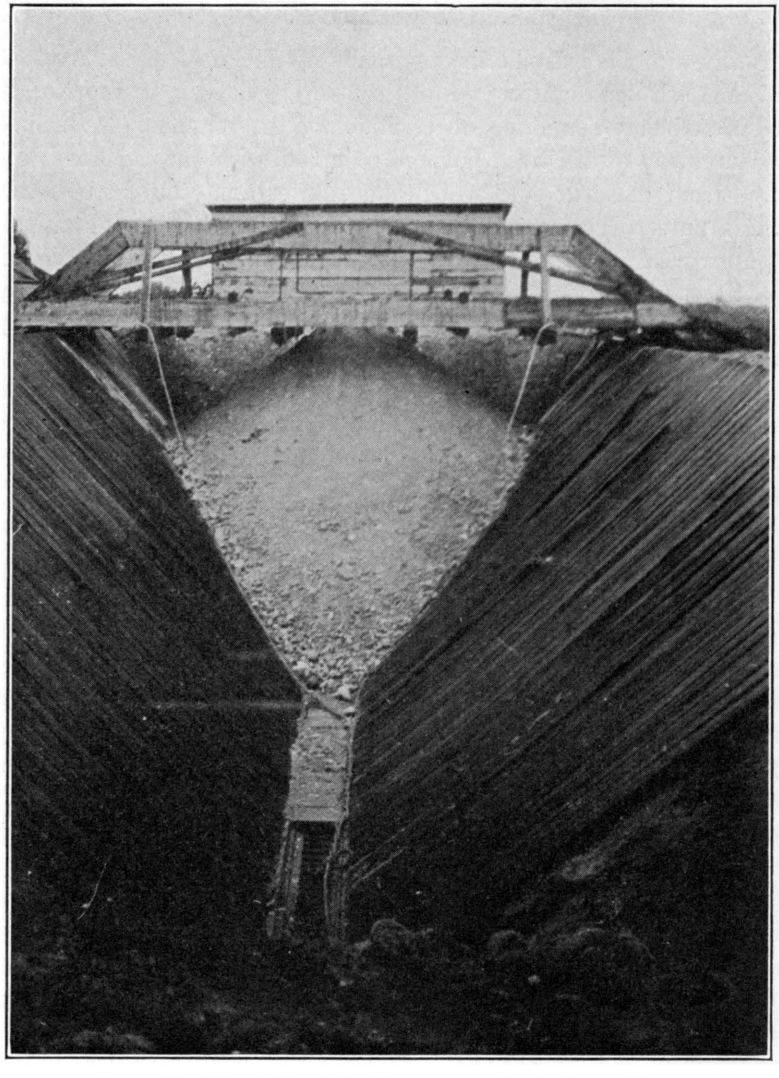


PLATE V.—Bin at Pumicite Company mill, Anthony, Kan.

## Milling.

Milling consists of two steps, drying and screening. The ash is carried by endless chain or elevator from the hopper to the upper end of an inclined revolving cylindrical dryer. The flame passes up the cylinder from the lower end. As the tube revolves the ash gradually works downward, drying as it does so, until it passes out the lower end. Then it is reëlevated to the top of the plant and put through a series of screens. The number of these depends upon the number of grades desired. As a final step the ash may be subjected to a blast of air which will separate the ash from the heavy impurities present. At the plant at Anthony (see Harper county) the attempt was made to classify the entire product by air, but it was not entirely sucessful, so it was abandoned and screens installed instead. The milled ash may be shipped loose in paper-lined box cars (as is the crude ash), or it may be sacked in 40-pound paper or 100-pound burlap bags.

## Production.

Kansas has led the United States in the production of volcanic ash since 1916. The production in 1926 was 48,869 tons, valued at $152,190. This is over 90 per cent of the country's total production. Eight companies reported production during 1926, but only two companies sold prepared ash and the total output was small. These were the Volcanic Ash Company of America (now the Pumicite Company) and the Clark Pumicite Company. The latter company was not operating its mill during the summer of 1927, but the Pumicite Company was.

The average price per ton received for crude ash in 1926 was $3, while the prepared material brought $8. Prices on crude seem to have dropped during the year, for the usual price being paid the independent producer in 1927 was $2 per ton f. o. b. On the other hand, prepared ash was bringing $14 per ton delivered. When carefully screened the very finest ash commands a fancy price, but the market for this material is small.

*Table of Production.*

*Volcanic ash produced in the United States and in Kansas from 1915 to 1926, in short tons.*

| Year. | United States. | Kansas. | Year. | United States. | Kansas. |
|---|---|---|---|---|---|
| 1915..... | 27,708 | *.... | 1921..... | 37,108 | 34,172 |
| 1916..... | 33,320 | 23,804 | 1922..... | 45,262 | *.... |
| 1917..... | 35,293 | *.... | 1923..... | 56,575 | 51,907 |
| 1918..... | 28,637 | *.... | 1924..... | 43,651 | 39,489 |
| 1919..... | 34,051 | *.... | 1925..... | 40,380 | 35,385 |
| 1920..... | 41,838 | *.... | 1926..... | 53,887 | 48,869 |

* Not listed by U. S. Geological Survey.

*List of Producers.*

| Company and address. | Location of mine. |
|---|---|
| J. C. Blackburn, Tasco, Kan. | ‡Tasco, Sheridan County. |
| Clark Pumice Co., Norton, Kan. | †‡Calvert, Norton County. |
| Cudahy Packing Co., 111 W. Monroe St., Chicago, Ill. | †‡Fowler, Meade County. |
| Davidson Pumice Co., Norton, Kan. | †Calvert, Norton County. |
| Robt. Ingram, Fowler, Kan. | †Fowler, Meade County. |
| National Silica Mfg. Co., Meade, Kan. | †‡Meade, Kan. |
| Thomas C. Perry, Fowler, Kan. | †Kismet, Seward County. |
| Pumicite Co.§, St. Louis, Mo. | †‡Anthony, Harper County, and ‡Hoxie, Sheridan County. |
| Western Spar Products Co., Dodge City, Kan. | †Southeastern Grant County. |

## Uses.

The uses for volcanic ash are many and varied. The first and most important use is as an abrasive. It is also used for a number of miscellaneous purposes, such as in heat insulation. A use of considerable future promise is in the cement industry. These uses will be considered separately and in detail.

### Abrasive.

An abrasive is a substance capable of grinding, polishing or cleansing surfaces. Volcanic ash is too fine and incoherent to be used in grinding, but its very fineness prevents it from producing visible scratches on metallic surfaces. Consequently it is ideal as a polishing and cleansing agent. Its efficiency is multiplied many fold by the extremely angular character of the individual particles. Each minute glass fragment contains a number of very sharp points which are all available for scraping off dirt, grease, and metallic stains.

Unadulterated ash can be used with very good results in cleaning and polishing all types of wood, glass and metallic surfaces, porcelain, sinks, kitchenware, etc. However, the scouring compounds on the market usually contain soap powder or bone ash beside. Old

§ Formerly the Volcanic Ash Company of America.
† Listed as a producer in 1926 by the United States Bureau of Mines.
‡ Operating during summer of 1927.

Dutch Cleanser is a cleaning compound marketed by the Cudahy company and containing 98 per cent ash. A number of manufacturers dilute the ash with sand and other cheap but much less efficient substances. Very fine ash is used in toothpastes and powders and as a high-grade silver polish. Further uses are in making mechanics' paste soaps, abrasive hand soaps, sweeping compounds, and rubber erasers.

### Miscellaneous Uses.

Because of its low heat conductivity and high porosity volcanic ash can be efficiently utilized in heat-and-cold insulation. It may be used in packing water and steam pipes, lagging boilers, and elsewhere where it is desirable to conserve heat or cold. Volcanic ash is also used as a filler in paints and other commodities, and in filtering oils for purposes of purification and clarification. An unusual use is for putting "linen" finish on celluloid collars. It has also been used in dynamite.

### Cement.

Two types of cement are made with volcanic ash, puzzolan and trass or tufa cements. The former type was used by the Romans some eighteen centuries ago and a great number of their structures are still standing. It consists of two parts (by volume) of volcanic ash and one part of slaked lime. These ingredients are mixed and ground to a fine mixture which possesses hydraulic properties, or ability to set when mixed with water. It is especially valuable in seaworks, and some of those constructed by the Romans are in use to-day.

The Italian ash (called puzzuolana) is secured from volcanic deposits at Pozzuoli, a small town near Naples, which gives the cement its name. It is also obtained in southeastern France and the Azores. Material from the latter locality is shipped to Portugal, where it is used very satisfactorily in important buildings, harbor works, etc. A similar ash, called tosca, is shipped from the Canary Islands to Spain. Santorin, a volcanic ash occurring on the island of Santorini, in the Grecian archipelago, was extensively used for making hydraulic cement in the construction of the Suez Canal and is now exported in large quantity for similar purposes. A relatively small amount of puzzolan cement is manufactured in the United States annually, with blast-furnace slag instead of volcanic ash.

Puzzolan cement has two drawbacks: It has less resistance to

wear and it sets much more slowly than does Portland cement. To overcome these objections the modern practice in Italy is to mix Portland cement with pozzuolana, and a concrete is secured which is especially valuable for sea works. But this produces what is termed trass or tufa cement, which is the next type to be considered.

According to Eckel[19] "Trass is a pale yellowish to grayish rock, rough to the feel, composed of an earthy or compact pumiceous dust mixed with fragments of pumice, trachyte, carbonized wood, etc. It is, so far as origin is concerned, an ancient volcanic mud. Trass occurs along the Rhine in Rhenish Prussia, from Köln on the north to Coblenz on the south." It has been used very extensively abroad as an ingredient of cement. Tufa (a better term is tuff) is volcanic ash which may or may not be mixed with coarser volcanic ejectmenta and fragments of foreign material. It has been used in concrete in Nebraska and California and the Pumicite Company, of St. Louis, is now engaged in exploiting its use for general paving and construction purposes.

The preparation of trass or tufa cement is simple. The volcanic material is finely ground (if necessary) and mixed with Portland cement in varying proportions. The Pumicite Company recommends a mixture of 10 per cent ash and 90 per cent cement, but in California and Nebraska 50 per cent mixtures have been used with satisfactory results, and experiments show that even higher proportions of ash are possible. Due to its incoherent character, the volcanic ash of the Great Plains would not have to be ground, and the major expense in the preparation of this type of cement would thus be eliminated.

The largest use so far made of tufa cement in the United States was in the construction of the Los Angeles aqueduct. Three deposits of volcanic tuff were located along the line of construction, and grinding plants were built at each location. The powdered tuff was mixed with cement on a 50-50 basis and the resulting compound was employed in making a large amount of the concrete used in this 250-mile aqueduct. The saving was approximately $1 a barrel. High freight rates which made the cement unusually expensive were responsible for a part of the saving, but on the other hand the grinding expense added to the cost of the tuff.

The use made of tufa cement in constructing the Los Angeles aqueduct has been described in "Construction of the Los Angeles

19. Eckel, Edwin C. "Cements, Limes, and Plasters," p. 578.

Aqueduct, Final Report," by the board of public service commissioners of the city of Los Angeles, 1916. A description of tests made of tufa concrete are included in a paper by the assistant chief engineer, J. P. Lippincott, published in the "Transactions of the American Society of Civil Engineers," vol. 76, p. 520; 1913. Figs. 2 and 3 are copied from this paper. They show the strength of tufa cement at various ages compared with the strength of monolith, a portland cement, over a similar period. Fig. 2 shows that the tufa cements are slower than the standard cement in getting their strength, but they usually attain equal strength in from 6 to 10 days and from then on are stronger (fig. 3). In fact, through the entire period of testing (two years) the tufa cement showed a continued growth in strength. Standard cement, on the other hand, shows a loss in strength between one and four months, and then a slow recovery. It was further observed by the engineers that the tufa concrete had greater flexibility than the straight cement concrete.

Another interesting result of the tests made during the construction of the aqueduct is quoted from page 106 of the final report:

"One of the peculiarities of the tufa cement is that larger amounts of tufa than 50 per cent can be added without seriously interfering with its ultimate strength. Careful tests, made both by the laboratories of the city and by government laboratories, show that the tufa combines chemically as well as mechanically with hydraulic cement. A test run of 80 per cent tufa and 20 per cent hydraulic cement gave a strength of 20 pounds in three days, 75 pounds in seven days, 155 pounds in three months, and 300 pounds in six months. For the purpose of testing these leaner mixes in actual construction, a mill run of 100 barrels was made at Haiwee of 75 per cent tufa and 25 per cent hydraulic cement, and put in 100 feet of the lining of the open aqueduct north of the Haiwee reservoir to compare with the 50 per cent blends that were adopted as standard. Little difference could be distinguished between the two concretes in the work itself. This indicates that a lean cement of this nature, which would be impervious to water, could be successfully used in the lining of open irrigation canals."

The conclusions in regard to tufa concrete are quoted from page 109:

"In conclsion it may be stated that tufa, when finely ground with cement, and used in concrete, combines both chemically and mechanically; blends of 50 per cent, when mixed with sand, give greater tensile strengths, after 10 days, than straight cement mixed with the same proportion of sand; the leaner the mixture, the greater the relative superiority of the tufa cement; in compression, the tufa cement concrete is about 20 per cent less strong in richer mixtures of 1-2-4, and as strong in leaner mixtures of 1-3-6; tufa cements in tension show a continued growth in strength with age up to five years, and in

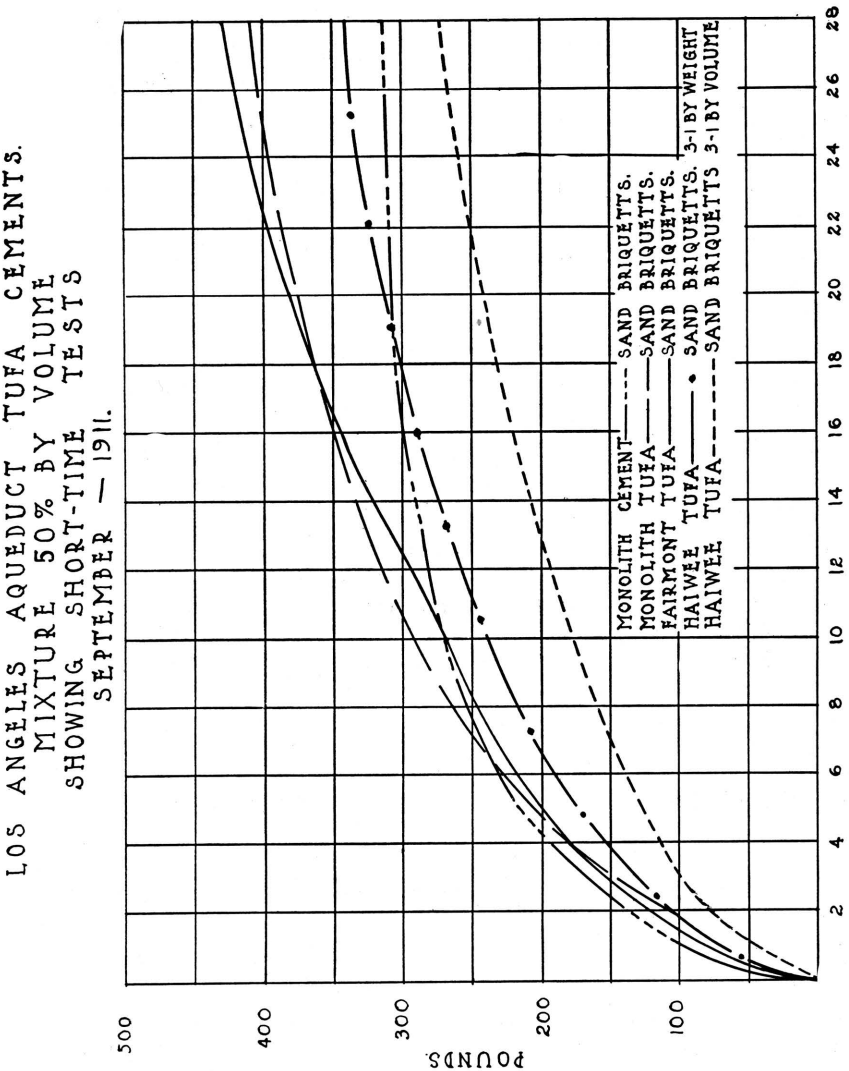

LOS ANGELES AQUEDUCT TUFA CEMENTS.
MIXTURE 50% BY VOLUME
SHOWING SHORT-TIME TESTS
SEPTEMBER — 1911.
POUNDS
500
400
300
200
100
2
4
6
8
10
12
14
16
18
20
22
24
26
28
TIME IN DAYS.
MONOLITH CEMENT ---- SAND BRIQUETTS.
MONOLITH TUFA —— SAND BRIQUETTS.
FAIRMONT TUFA —— SAND BRIQUETTS.
HAIWEE TUFA —•— SAND BRIQUETTS. 3-1 BY WEIGHT
HAIWEE TUFA - - - - SAND BRIQUETTS 3-1 BY VOLUME

FIGURE 2.

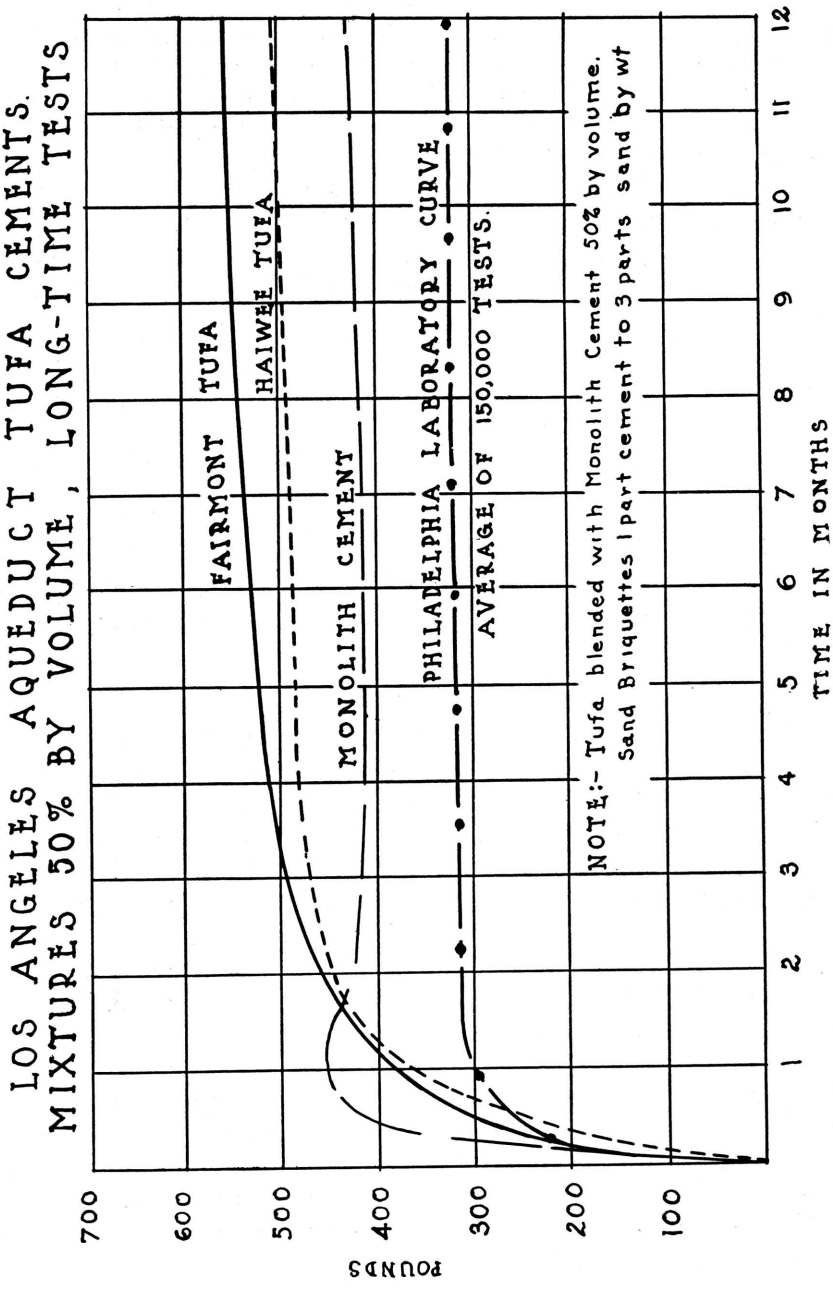

LOS ANGELES AQUEDUCT TUFA CEMENTS.
MIXTURES 50% BY VOLUME, LONG-TIME TESTS
FAIRMONT TUFA
HAIWEE TUFA
MONOLITH CEMENT
PHILADELPHIA LABORATORY CURVE
AVERAGE OF 150,000 TESTS.
NOTE:- Tufa blended with Monolith Cement 50% by volume.
Sand Briquettes 1 part cement to 3 parts sand by wt
POUNDS
700
600
500
400
300
200
100
1
2
3
4
5
6
7
8
9
10
11
12
TIME IN MONTHS

FIGURE 3.

this respect are superior to straight cements, which usually show declining strengths. Tufa concretes must be handled with greater care with reference to both cold and drying, and forms should be left in place about one-third longer. In massive work this feature is negligible. From the fact that the tufa cement is more finely ground, and, in part combines mechanically with other aggregates, carrying the gradation of fineness one step further, it makes a denser and more impervious concrete."

The tufa used in California resembles the German trass, used in the manufacture of trass cements. The report states that the tests made on the aqueduct are entirely in harmony with those made by the German government on trass cements. However, the tests made by the Los Angeles engineers are open to the objection that they do not cover a long-enough period of time. This objection is in part answered by the service given by the aqueduct in the fifteen years in which it has been in use. Volcanic ash has also been successfully used in the construction of a dam across the Niobrara river at Valentine, Neb.

The California tuff has a silica content of from 68 to 71 per cent. It differs in no essential from the volcanic ash of Kansas except that it is a consolidated rock instead of a powder. This difference is all to the advantage of the Kansas material, for grinding is unnecessary.

## Future.

The future for the volcanic ash industry in Kansas is promising. There is no reason why extensive use should not be made of ash in cement. Six and one-half million barrels of Portland cement were produced in this state in 1925. Had this cement contained 10 per cent ash there would have been a demand for 122,200 additional tons of volcanic ash during that year. This amount is over three times the 1925 production. Missouri and Iowa together produce twice as much cement as Kansas, and as those states are without commercial ash deposits of their own they would afford additional market for the Kansas material.

The average price charged by the cement producer in Kansas in 1925 was $1.66 per barrel. This is equivalent to $8.83 per short ton. Volcanic ash can be supplied in quantity at a price much lower than that. Consequently its utilization in cement would cheapen the cost of the product without lowering its industrial value.

The present method of marketing ash for use in concrete is to sell it to the contractor, who mixes it with cement on the job. This is

an expensive and inefficient procedure. A far better method would be to sell the ash directly to the cement manufacturer, who could mix the materials in his plant and market the product himself. He could not label it Portland cement, because of the restricting definition of that term, but his product would be in no way inferior to Portland cement. Another name could easily be coined.

By no means all of the demand for ash and pumice for abrasive and miscellaneous uses is met by domestic production. One hundred and thirty thousand dollars' worth of pumice was imported from Sicily in 1926. Much of it is ground and is no different from the Kansas ash. But the high freight rates between this state and the Atlantic coast make competition with the Sicilian product difficult on the eastern seaboard. With a sufficiently high tariff it would be possible for domestic ash and pumice (California) to displace foreign pumice except for the finest quality lump used in exacting lithographic work and in finishing copper, silver and other metals before plating. F. J. Katz[20] has calculated that this amount does not exceed 100 tons annually.

A light-weight structural material of high heat-insulating value has been prepared in France from pulverized pumice with silicates as binders.[21] This has been used in building furnaces for glass works from which a minimum of heat escapes. Similar use could be made of volcanic ash.

An artificial pumice has been made in Germany from ground sandstone and clay. Due to the low cost of volcanic ash in the United States it is not believed that the domestic manufacture of artificial pumice or its importation from abroad is commercially possible.

20. Mineral Resources of U. S. for 1918, Pt. II, p. 1184, U. S. Geol. Surv.

21. Jour. Ind. Eng. Chem., vol. 13, 2, p. 171; Feb., 1921. Reported by Ladoo (see bibliography).

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