A STRATIGRAPHIC STUDY OF THE INSOLUBLE RESIDUES OF THE COUNCIL GROVE GROUP LIMESTONES OF THE MANHATTAN, KANSAS, AREA

by

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INTRODUCTION

Purpose and Scope of the Investigation

The economic importance of the Paleozoic rocks throughout the Midcontinent region of North America, particularly as a source of petroleum, has led to an increasing desire for a more complete understanding of that part of the geologic section. To provide some of the basic data, the Kansas Geological Survey in July, 1937 began a study of the older Paleozoic rocks in the subsurface of Kansas.

The study was first assigned to Raymond P. Keroher as part of his duties and later, in July, 1941, Jewell Kirby was also assigned to the work, which was completed during the winter of 1944. Keroher and Kirby (1948, p. 17) found that the distinguishing characteristics of the chert, sand, and shale intermixed in the older Paleozoic dolomites are largely obscured in samples as they come from the well but may be brought out satisfactorily when they are studied as insoluble residues. McQueen (1931) and others have shown that, in many cases, dissolving the soluble carbonate, usually in the form of dolomite or calcite, from a rock sample by means of hydrochloric acid leaves an insoluble residue that may be identified more readily than the original sample.

All previously published work in the insoluble residues in Kansas and the remainder of the Midcontinent region of North America has been restricted to the Pre-Permian portion of the Paleozoic section. This report has been prepared to present new data relative to the residues of the limestones, both formations and member, of the Council Grove Group of the Permian System that crop out in the area surrounding Manhattan, Kansas.

The specific purpose of this investigation is to describe as exhaustively as possible the character and distribution of the insoluble residues of the limestones of the Council Grove Group and to determine whether or not these limestones can be differentiated on the basis of their content of insoluble residues. The results of the investigation indicate that the insoluble residues are diagnostic not only of the formations but also of the members within a formation.

The study is limited to limestones of the Council Grove Group exposed at the surface in the vicinity of Manhattan. The approach to the local study has been the correlation within the selected area of stratigraphic units that are lithologically similar. Except in the case of the Cottonwood limestone member of the Beattie limestone there has been no attempt made to differentiate between all of the persistent zones that can be distinguished in the several beds of limestone investigated.

Definition of Insoluble Residue

An insoluble residue may be defined as the material remaining after rock fragments have been digested in acid (Ireland, 1950). Hydrochloric or muriatic acid is usually used as the reagent, but acetic acid is used if the preservation of delicate fossils or other structures is desired. Residues such as shale, gypsum, pyrite, anhydrite, limonite, glauconite, and celestite are not siliceous; therefore, the term siliceous residues cannot be applied to this material although the term is sometimes used. The predominant residues are quartz and various types of chert, of which chert is the more diagnostic for purposes of stratigraphic identification and correlation.

Location and Extent of the Arsa Investigated

The area investigatsd is located in ths northeastern portion of the State of Kansas and includes about 261 square miles (Fig. 1). It includes portions of three counties: southwsstern Pottawatomie County, northwestern Geary County, and the greater part of eoutheastern Riley County.

Manhattan is the largsst city in the area which might thus be properly termed the "Manhattan Area."

Stratigraphic Units Samplsd

The Council Grovs Group is a division of the Psrmian System which comprises a thickness of about 320 feet of limsstone and shals. The limsstone formations and membsrs of this group wsre the stratigraphic units sampled in this study. The classification of thees sampled units is that establiehsd by ths State Geological Survsy of Kansas (Moore et al., 1951). The only deviation from this classification was mads in ths subdivision of the Grsnola limestone; the Sallyards limsstone member is not a significant unit in the Manhattan area and was not sampled.

The samplsd units are:

- Council Grovs Group
  - Funston limestone
  - Crouse limestone
  - Bader limeetons
    - Middlsburg limestone member
    - Eiss limestons member
  - Beattie limestone
    - Morrill limestone member
    - Cottonwood limsstone member

Grenola limestone

Neva limestone member

Burr limestone member

Red Eagle limestone

Howe limestone member

Glenrock limestone member

Foraker limestone

Long Creek limestone member

Americus limestone member

The sequential relationship of these units is shown in Fig. 2.

Investigation Procedure

General. The procedure employed in the preparation of samples is a composite of the methods developed by previous workers on insoluble residues. Workman (unpublished manuscript, 1950) has been one of the leading workers in this field, especially in his use of the fine insoluble residues. McQueen (1931) was one of the first of the recognized authorities to publish methods of preparation, terminology, and practical application of insoluble residues to surface and subsurface correlation and the identification of calcareous rocks, but to date he has not published or done extensive research on the fine residues.

Most of the work on residues in Texas, especially that done by the Research Laboratory, Midland, Texas, was developed independently of that of McQueen and a confusion in nomenclature resulted and still exists (Vanderpool, 1950). However, in 1946 Ireland called a conference of active workers from the Central United States which resulted in the publication of a standardized terminology (Ireland et al., 1947). This investigation utilizes the standardized terminology established by the 1946 conference.

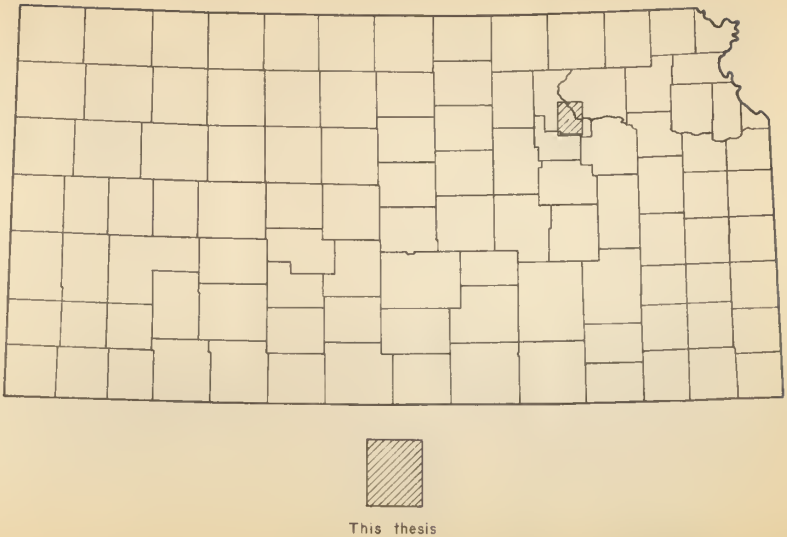

Fig. 1. Index map of Kansas showing area covered by this thesis.

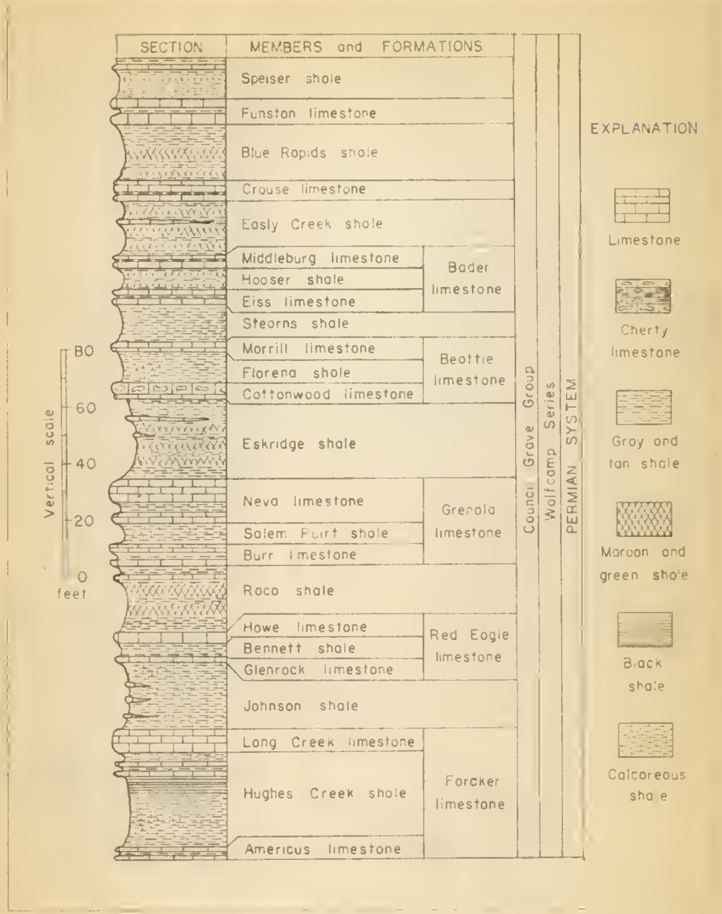

Fig 2. Generalized stratigraphic section of the Council Grove Group.

Field Procedure. The collection of samples in the field was so done as to make them truly representative of the source rock. They consisted of unweathered chips from outcrops and were without lichen, soil, or other extraneous matter.

The samples were obtained by making a channel on the exposed surface of the outcrop with a chisel and hammer after the weathered surface has been removed by the same tools. Such a channel in the Cottonwood limestone member of the Beattie limestone is shown on Plate I, Fig. 1. The rock chips were caught on a cloth spread at the base of the outcrop and then placed in a paper bag which was appropriately labeled as to sample number, source rock, and geographic location. Placed in the bag with the sample was a piece of paper which included the same information as that on the bag plus a lithological description of the sampled rock.

Laboratory Procedure. In the laboratory the samples were put in metal containers which were then placed in an electric oven and heated to a temperature less than that of the kindling point of paper. The samples were baked in this manner for two hours or more to liberate any water that might be present in the interstices of the rock. The temperature was kept low because white cherts, if they contain iron, may change to orange or red. Under conditions of high-temperature heating, the valence of iron may be changed (Kerohor and Kirby, 1948, p. 10).

The removal of the water from the sample made easier the next step which was that of crushing the rock to the desired size. Dehydration of the rock made it more brittle and thereby produced less powder while it was being crushed. The fine powder that coated the crushed fragments was thus kept to a minimum and was an aid in obtaining a more uniform volume-weight ratio of the measured samples before they were digested in acid.

EXPLANATION OF PLATE I

Fig. 1. Close-up of channel produced while obtaining sample from the Cottonwood limestone member. Bluemont Hill, Manhattan, Kansas.

Fig. 2. An exposure of the Cottonwood limestone member. Stagg Hill, Manhattan, Kansas.

PLATE I

Fig. 1.

Fig. 2.

Rock fragments that will pass through a No. 4 sieve and be retained on a No. 10 sieve approximate those that are obtained from cable-tool well samples. This range of fragment sizes will give nearly uniform volumetric measures. The rock crusher was adjusted to pass rock fragments smaller than a No. 4 sieve. As the crushed material came from the crusher, it was caught on a No. 10 sieve, screened, and the retained fraction was kept for further study.

The crushed samples were reduced to the desired volume by the quartering method. It was determined from preliminary investigation that a unit volume of 10 drams of sample would be a satisfactory amount to be digested. This volume of sample, after digestion, left enough residue for the purpose of classification.

The weight of a unit volume of a sample was then determined. Weighing was done on an analytical balance to the closest 0.1 gram with the samples placed upon a paper filter disk. Use of the filter disk eliminated the necessity of weighing each container as the filter disks were uniform in weight. Later they were used for weighing both coarse and fine residues.

The weighed samples were then placed in appropriately numbered pint glass jars to be digested. The containers were next placed in a pyrex tray which was set under a chemical laboratory hood. Approximately 125 cc of muratic acid (commercial hydrochloric acid) diluted to half strength with ordinary tap water was used to treat each sample. Acid was added until the effervescence ceased. As the action of acid on limestone is quite vigorous, the application of acid must be slow to prevent the froth from spilling out of the glass.

When digestion was complete, time was allowed for the fine residue to settle. The acid was then siphoned off and the container was filled with water, agitated, and the residues again allowed to settle. The washing was repeated five or six times to remove all traces of acid.

The fine residues were then separated from the coarse residues by decanting. They were caught in a paper filter disk similar to the one used for weighing the sample before digestion. Each filter disk was labeled with the same number as that on the container from which the sample came. The fine residues were kept in the filters until all excess water had drained. They were then heated until all water had been removed. As the scales were already adjusted to balance with a filter disk, the dried fine residues were weighed in the filter disks that were used to catch them. Next the caked fine residues, particles of fine silt and clay size, were pulverized to pass through a No. 18 sieve. They were then placed in labeled 2-dram vials and the percentage of original unit volume was recorded. The procedure and equipment used to determine the percentage is explained more fully under coarse residues on pages 11 and 12.

While the fine residues were being processed, the coarse residues were being dried and measured. First they were transferred from the pint jars to 250 cc beakers and dried in a sand bath placed over a gas flame. The dried coarse residues were then transferred to a filter disk and weighed in the same manner as the original sample. They, too, were filed in labeled 2-dram vials.

The vials of both fine and coarse residues were then placed in a wooden block to determine the percentage of resi ue by volume. The block is a piece of 2 by 4 inch lumber about 6 inches long into which holes 3/4 inch in diameter had een drilled in such a manner that, when the vials are placed in them, the top of the shoulders of the vials would be flush with the upper edge of the block. The block was planed on one side to intersect the holes so that the vials were observable. It was painted with black enamel and ten equal horizontal divisions were ruled on the front face in white enamel, the ten divisions covering the length of the vial. Each division thus represented 10 percent by volume of the full vial but only 2 percent by volume of the unit volume used before digestion because the unit volume was five 2-dram vials of crushed rock.

After the percentage of coarse residue had been recorded, the residue was poured into a small tin pan, painted with black enamel, trapezoidal in shape, and measuring 3-1/2 by 2-1/4 inches, and with a depth of about one-fourth inch. The tapered end was cut off so that the material after it was examined could be returned to the vial.

A wide-field Bausch and Lomb stereoscopic binocular microscope with magnifications of 12.5 and 15 diameters was used for the examination of the coarse residues

Nomenclature and Symbols

General. Adoption of arbitrary symbols representing various types of residues obviated the necessity for detailed description during study, but in order to publish the results of observations it was necessary to use a number of descriptive terms. Most of these have been adopted from reports by Ireland et al., (1947), the Kansas Geological Survey (Lee, 1940, 1943), and the Missouri Geological Survey and Water Resources (Grohskopf and McCracken, 1949).

Nomenclature. The descriptive terms in this report are defined as follows:

Anhedral: No crystal form developed.

Beekite: Botryoidal, subspherical, or discoidal accretions of opaque silica replacing organic matter, generally white. In this investigation beekite has been modified to include ostracod, molluscan, molluscoidean and echinoderm remains replaced by silica.

Chalcedonic: Transparent to translucent; smoky; milky; waxy to greasy;

may be any color, generally buff or blue-gray; may be finsly mottled.

Chalky: Uneven or rough fracture surface; commonly dull or earthy; soft to hard; may bs finely porous; essentially uniform composition; resembles chalk or tripolite. (Formerly referred to as "dead" or "cotton chert". This includes dull, unglazed porcellaneous material which grades into the glazed porcellaneous appearance of smooth chert.)

Chert: Cryptocrystalline varieties of quartz, regardless of color; composed mainly of petrographically microscopic fibers of chalcedony and/or quartz particles whose outlines range from easily resolvable to nonresolvable with binocular microscope at magnifications ordinarily used by geologists. Particles rarely exceed 0.5 mm in diameter.

Clay: Fine material of clay size.

Euhedral: Double terminated crystals; unattached.

Gilsonite: A black lustrous kind of asphalt; the mineral uintaite.

Granular: Chert; compact, homogeneous; composed of distinguishable grains, granules, or druses of relatively uniform size; uneven or rough fracture surface; dull to glimmering luster; hard to soft; may appear saccharoidal. (This type is frequently referred to as "crystalline".)

Granulated: Grains or granules partly cemented or loosely aggregated; saccharoidal; grades from angular to drusy; fine to coarse; particles rarely larger than 0.5 mm in diameter.

Massive: Used to include fine or coarse granular anhydrite or gypsum.

Mottled: Residue fragments with two or more colors or different materials interspersed and irregularly shaped and with boundaries either sharp or gradational; often appears flocculated; grades into speckled residue.

Ordinary: Smooth chert with even fracture surface; all colors, chiefly white, gray, or brown; may be mottled; approaches opaque; generally homogeneous, but may have slight evidence of granularity or crystallinity; grades into chalcedonic or granular chert.

Quartz: Clear, colorless quartz; not detrital.

Rounded: Spheroidal or ellipsoidal sand grains, coarse to fine; may be polished, frosted, or etched.

Sand: Grains of sand size, chiefly quartz, but may be composed entirely or partly of other minerals.

Silt: Grains of silt size, chiefly quartz, but may be composed entirely or partly of other minerals.

Smooth: Major type of chert with conchoidal to even fracture; surface devoid of roughness; may be botryoidal; homogeneous; no distinctive structure, crystallinity, or granularity.

Spongy: Texture that applies to aggregates of quartz, chert, silt, or clay in insoluble residues from which the soluble matrix has been removed and in which the individual openings are submicroscopic.

Subhedral: Crystal forms partly developed; may be loose, drusy, or granulated.

Subrounded; Polygonal grains or fragments but with well rounded edges and corners.

Tubular Silica: Small, highly contorted tubular forms of fragile silica (Schoewe, Keroher, and Keroher, 1937, p. 274). This is considered the residue termed "siliceous 'worm casts'" by Grohskopf and McCracken (1949, p. 15 and 23) because organic origin is implied in both references. In this investigation, however, it has been modified and is considered only as another type of coarse residue closely associated with the chert.

Unmodified: Residue uniform with no modifying characteristics.

<u>Sample Number Symbols</u>. The sample number symbols used in this report are

as follows:

Age of sampled rock:

P = Permian System

Limestone formations and members sampled:

f = Funston limestone

c = Crouse limestone

bam = Middleburg limestone member of the Bader limestone

bae = Eiss limestone member of the Bader limestone

bem = Morrill limestone member of the Beattie limestone

bec = Cottonwood limestone member of the Beattie limestone

gn = Neva limestone member of the Grenola limestone

gb = Burr limestone member of the Grenola limestone

rh = Howe limestone member of the Red Eagle limestone

rg = Glenrock limestone member of the Red Eagle limestone

fl = Long Creek limestone member of the Foraker limestone

fa = Americus limestone member of the Foraker limestone

"Zones" of the Cottonwood limestone member of the Beattie limestone:

A = Uppermost zone

B = Zone between A and C

C = Zone between B and D

D = Bottom-most zone

Sample sequence:

1 through 15 inclusive = order of samples as collected in field

Counties:

G = Geary

P = Pottawatomie

R = Riley

The sample numbered Pgn-3-R would thus be the third sample collected from the Neva limestone member of the Grenola limestone of the Permian system in Riley County, Kansas.

The sample numbered C-12-G would be the twelfth sample collected from the "C" zone of the Cottonwood limestone member of the Beattie limestone in Geary County, Kansas.

Fine Residue Color Symbols. The color of the fine residues was obtained by comparing them with examples of the Rock Color Chart. This chart was prepared in 1948 by the Rock-Color Chart Committee of the National Research Council and is now distributed by the Geological Society of America.

The following color symbols, and their equivalent colors, are used in this study:

Symbol	Color
5 Y 4/1	Olive gray
5 Y 6/1	Light olive gray
5 Y 6/4	Dusky yellow
5 Y 7/1	Yellowish olive gray
5 Y 7/2	Yellowish gray
5 Y 8/1	Yellowish gray
5 YR 4/1	Brownish gray
5 YR 6/1	Light brownish gray
5 YR 6/4	Light brown
5 YR 7/2	Grayish orange pink
10 YR 5/4	Moderate yellowish brown
10 YR 6/2	Pale yellowish brown
10 YR 6/6	Dark yellowish orange
10 YR 7/4	Grayish orange

<u>Coarse</u> <u>Residue</u> <u>Symbols</u> <u>and</u> <u>Colors</u>. Ths following symbols and colors wers used in this report to represent the coarse residues:

Symbol	Coarss Residue
	Chert
	Chalky
	Granular
	Mottlsd
	Nodular
	Oolitic
	Smooth
	Spongy
	Beekite
	Tubular silica
	Quartz
	Subhedral
	Anhedral
	Celestite
	Gypsum
	Glauconits
	Limonits
	Magnetite
	Arenaceous material
	Argillaceous material
	Clay (massive to pellets)
	Clay (spongy)

It should be noted that tubular silica and beekite have been givsn the same color assigned to chert. Crushed fragmsnts of these materials possess the optical properties of chert and thus are considered a variety of it. The coarse residue constituent symbol that accompanies the residue color is not shown on the circlegrams because of the difficulty of reproducing them; however, they are employed in the bar graphs.

DESCRIPTION OF INSOLUBLE RESIDUES

Introduction

It is the purpose of this part of the report to present and describe the characteristic and diagnostic insoluble residue assemblages of the limestones of the Council Grove Group and to evaluate them as a basis for the correlation of these limestones in the Manhattan Area.

Funston Limestone

Description of the Formation. The Funston limestone consists of two or more beds of limestone separated by shale partings in the lower or middle part. The limestones are soft, sandy appearing, massive, and weather blocky to platy and porous. They are tan to gray brown and weather tan but a veneer of maroon stain usually conceals the surface of the upper layer of limestone. Calcareous nodules are sometimes present in this unit in the southern part of its outcrop area. No fossils were observed in this formation in the field. The average thickness of the Funston limestone is about 8 feet, and it forms a well-developed hillside bench.

(Note: This and the following descriptions are adapted from those presented in a thesis by M. R. Mudge on file in the Library of Kansas State College. The descriptions by Mudge have been amplified by the author's observations.)

The stratigraphic relationehip of ths Funston limestone to other units of the Council Grove Group is ehown in Fig. 2.

Register of Sampled Localitiss. Outcrops of ths Funston limeetone euitabls for sampling were found at the five following locations:

Sample Number	Type of Outcrop	Legal Description
Pf-1-R	Hillsids	SE¼NW¼ eec. 32, T. 10 S., R. 8 E. (Riley County, Kans.)
Pf-2-R	Road Cut	NE¼NE¼ sec. 33, T. 10 S., R. 8 E. (Riley County, Kans.)
Pf-3-R	Road cut	SE¼NE¼ ssc. 7, T. 11 S., R. 8 E. (Riley County, Kans.)
Pf-4-R	Road cut	NE¼NE¼ ssc. 10, T. 10 S., R. 7 E. (Riley County, Kane.)
Pf-5-R	Road cut	SW¼SW¼ ssc. 9, T. 9 S., R. 7 E. (Rilsy County, Kans.)

Description of the Insolutls Residues. The clay and fins silt obtained from ths Funston limestone as fine residuee are ysllowieh-gray in ths southeastern part of the area inveetigatsd, but change to grayish-orange in the northwestsrn and central esctions. Ths avsrage percentage of eample by weight of fins residus is 3.5 but the percentage of eample by volume ie 7.6 (Figs. 3a and 3b).

Chert, in the form of light-gray tubular silica, ie the major coares rseidue constituent in all samples; all of them ehow not less than 95 percent by volume (Fig. 3). White, chalky, nodular chert appears in only one sample, Pf-4-R. A strong trace of silicifisd valvee of the ostracod Cavellina was found in sample Pf-1-R (Fig. 3c). Celestite and gypsum are present ae minor traces in eamples Pf-2-R, Pf-4-R, and Pf-5-R. The coarss reeidue constitutee an average of 1.3 percent by wsight but 3.7 percent by volume of sample (Figs. 3a and 3b).

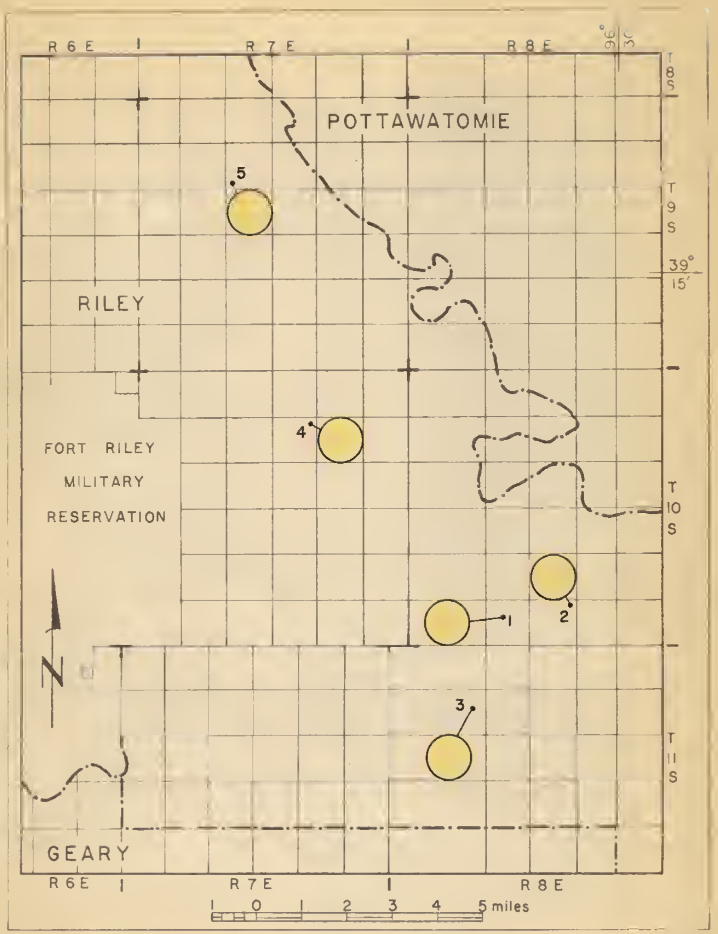

Fig. 3. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the Funston limestone.

Sample number	Location	Sample weight (gram)	Residue						
			Coarse			Fine			
			Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
Pf-1-R	SE¼NW¼ sec. 32, T. 10 S., R. 8 E. Hillside outcrop	54.4	1.0	1.8	6.0	1.5	2.8	4.0	5 Y 7/2
Pf-2-R	NE¼NE¼ sec. 33, T. 10 S., R. 8 E. Road cut	61.1	1.1	1.[illegible]	4.5	2.8	4.6	9.0	5 Y 7/2
Pf-3-R	SE¼NE¼ sec. 7, T. 11 S., R. 8 E. Road cut	57.2	0.5	0.9	3.0	2.0	2.2	6.0	5 Y 7/2
Pf-4-R	NE¼NE¼ sec. 10, T. 10 S., R. 7 E. Road cut	60.1	0.4	0.7	2.0	3.4	3.3	11.0	10 YR 7/4
Pf-5-R	SW¼SW¼ sec. 9, T. 9 S., R. 7 E. Road cut	59.7	0.7	1.2	3.0	2.6	4.4	8.0	10 YR 7/4
Average	- - - - - - - - - - - - - - - -	58.6	0.7	1.3	3.7	2.4	3.5	7.6	- - - - -

Fig. 3a. Sample data for the Funston limestone.

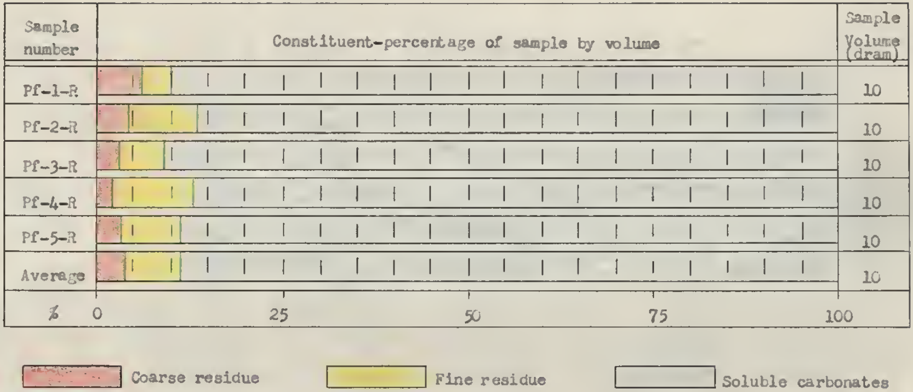

Fig. 3b. Constituent-percentage of sample by volume from the Funston limestone.

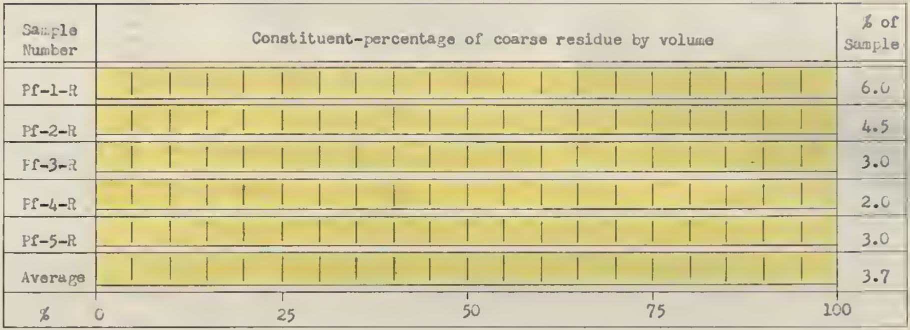

Fig. 3c. Constituent-percentage of coarse residue by volume from the Funston limestone.

Stratigraphic Correlation by the Use of Insoluble Residues. Correlation of the Funston limestone based upon insoluble residues is believed to be possible. The residue assemblage shows a persistently high percentage of tubular silica which is characteristic of the Funston (Fig. 3). The relative stratigraphic sequence and difference in diagnostic residues found in the underlying Crouse limestone readily identify this formation.

Crouse Limestone

Description of the Formation. The upper part of the Crouse limestone consists of thin-bedded limestones separated by numerous thin partings of shale whereas the lower part is massive, granular, and has a sandy appearance throughout. The limestones are hard, dense, weather blocky to platy and are gray and brown but weather tan to gray. Fossil fragments are common, but well preserved specimens are almost lacking. The average thickness of the Crouse limestone is about 8 feet and two hillside benches are usually formed by this limestone in the southeastern part of Riley County.

The stratigraphic relationship of the Crouse limestone to the other units of the Council Grove Group is shown in Fig. 2.

Register of Sampled Localities. Outcrops of the Crouse limestone were sampled at the five following locations:

Sample Number	Type of Outcrop	Legal Description
Pc-1-R	Hillside	SE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 32, T. 10 S., R. 8 E. (Riley County, Kans.)
Pc-2-R	Road cut	NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 33, T. 10 S., R. 8 E. (Riley County, Kans.)
Pc-3-R	Road cut	SE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 7, T. 11 S., R. 8 E. (Riley County, Kans.)
Pc-4-R	Road cut	NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 10, T. 10 S., R. 7 E. (Riley County, Kans.)

Sample Number	Type of Outcrop	Legal Description
Pc-5-R	Stream bank	SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 9, T. 9 S., R. 7 E. (Riley County, Kans.)

Description of the Insoluble Residues. The fine residue obtained from the Crouse limestone ranges from pale yellowish-brown in the northwestern and central parts of the area to yellowish-gray which predominates throughout the southeastern section. The average sample of Crouse limestone produces 5.6 percent by weight and 10.8 percent by volume of fine residue (Figs. 4a and 4b).

Limonite replacing fragments of bryozoans and brachiopods are associated with crystalline sphalerite is the predominant coarse residue in all samples (Fig. 4c). The amount of limonite ranges from about 90 percent in the northwest to approximately 75 percent by volume in the southeastern part of the area (Fig. 4). Fine, loose, unmodified and subhedral quartz is a common residue constituent and composes approximately 10 percent of an average sample. Tubular silica is present in all samples but ranges from a strong trace in the northwest to about 10 percent of sample in the southeast (Fig. 4). Some of these "worm casts" are stained by limonite. Fine, granular gray chert containing molluscoidean fragments is a minor constituent of the coarse residues from this stone. Traces of selecitic gypsum and zircon were found in nearly all samples. The coarse residues constitute an average of 0.2 percent by weight and 0.1 percent by volume of sample (Figs. 4a and 4b).

Stratigraphic Correlation by the Use of Insoluble Residues. Fossiliferous limonite associated with sphalerite is the diagnostic residue of the Crouse limestone (Fig. 4c). The relatively low percentage of fine, loose, subhedral quartz associated with the persistently high percentage of limonite makes stratigraphic correlation comparatively simple as the underlying Middleburg

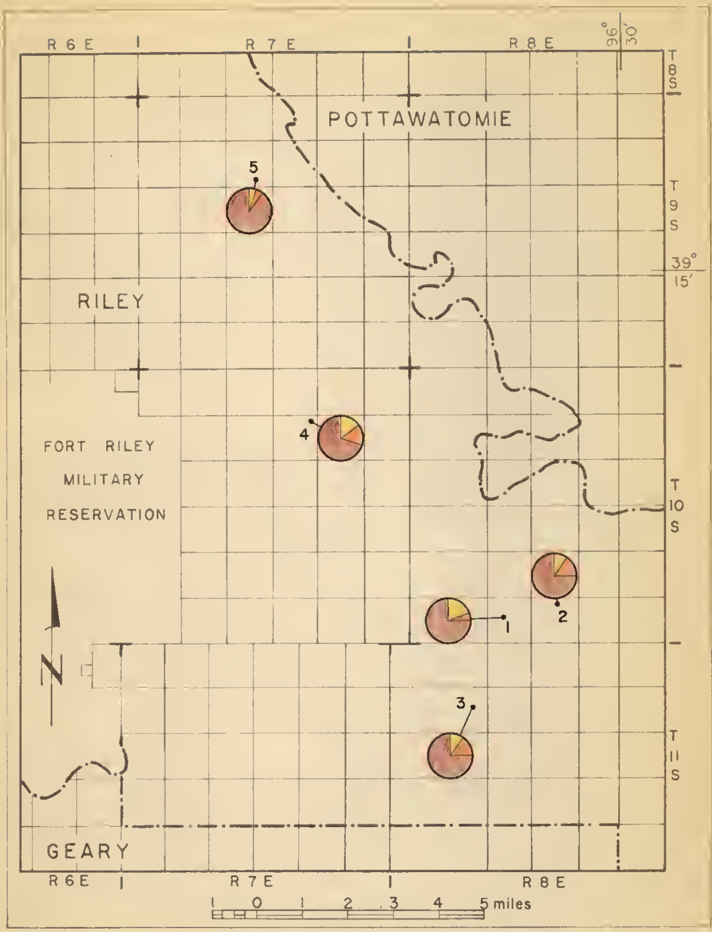

Fig. 4. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the Crouse limestone.

Sample number	Location	Sample weight (gram)	Residue						
			Coarse			Fine			
			Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
Pc-1-R	SE¼NW¼ sec. 32, T. 10 S., R. 8 E. Hillside outcrop	63.0	0.1	0.2	T	3.4	5.4	9.0	10 YR 6/2
Pc-2-R	NW¼NE¼ sec. 33, T. 10 S., R. 8 E. Road cut	59.3	0.3	0.5	0.5	3.2	5.4	12.0	5 Y 7/2
Pc-3-R	SE¼NE¼ sec. 7, T. 11 S., R. 8 E. Road cut	61.4	0.1	0.2	T	3.7	6.0	11.0	5 Y 7/2
Pc-4-R	NE¼NE¼ sec. 10, T. 10 S., R. 7 E. Road cut	60.5	0.1	0.2	T	3.3	5.5	11.0	10 YR 6/2
Pc-5-R	SW¼SE¼ sec. 9, T. 9 S., R. 7 E. Stream bank	62.0	0.1	0.2	T	3.4	5.5	11.0	10 YR 6/2
Average	- - - - - - - - - - - - - - - -	61.2	0.1	0.2	0.1	3.4	5.6	10.8	- - - - -

Fig. 4a. Sample data for the Crouse limestone.

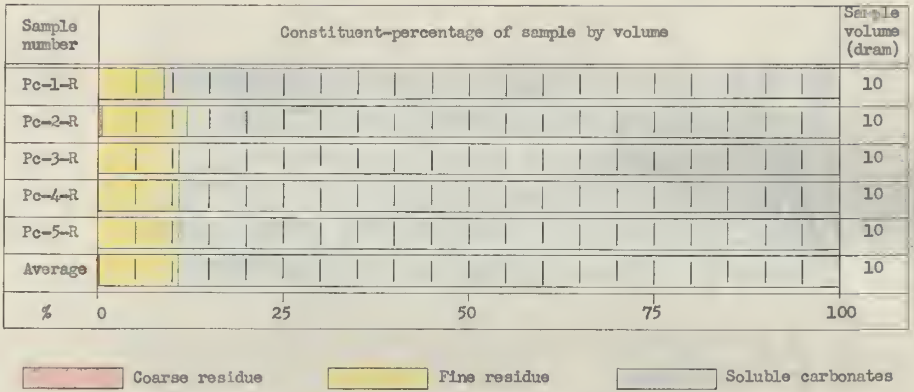

Fig. 4b. Constituent-percentage of sample by volume from the Crouse limestone.

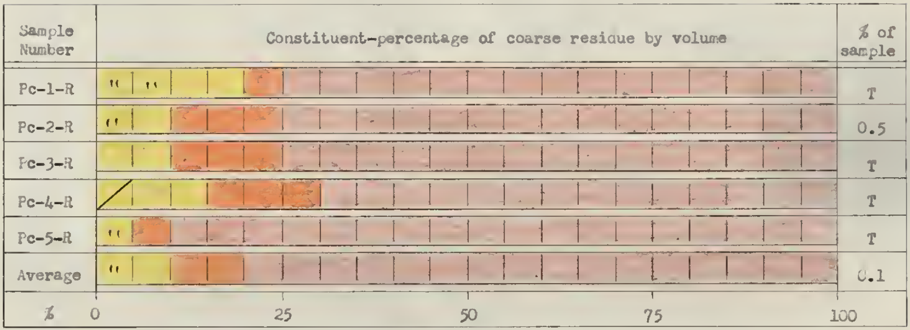

Fig. 4c. Constituent-percentage of coarse residue by volume from the Crouse limestone.

limestons member of the Bader limsstone producss residues with a largs amount of quartz and chert and the overlying Funston limestone gives residues composed almost entirely of tubular silica (Figs. 5c and 3c).

Middleburg Limestone Member of the Bader Limestone

Description of ths Member. The Middlsburg limestone member consists of two limestones which are usually separated by a dark-gray or black shale which is silty, calcareous, and thin bsddsd. The limestones are massive, hard, dsnse, and somswhat crystalline. Thsy are gray to olivs drab and usually weather light gray, but in most exposures ths weathered surface is covered with light-maroon stains. Pelecypods, brachiopods, and crinoid columnals were found in the basal limestons laysr while algae occur locally in ths upper bed. Ths average thicknsss of this membsr is about 4 feet and, although it seldom crops out conspicuously, it forms an identifiable small bench between the Crouse and Eiss limestones on soms hillsides.

The stratigraphic relationship of the Middlsburg limestons member with the other units of ths Council Grovs Group is shown in Fig. 2.

Register of Sampled Localitiss. Five outcrops of the Middleburg limestone member were sampled at the following locations:

Sample Number	Typs of Outcrop	Legal Description
Pbam-1-R	Hillside	SE¼NW¼ sec. 32, T. 10 S., R. 8 E. (Riley County, Kans.)
Pbam-2-R	Road cut	NW¼NE¼ sec. 33, T. 10 S., R. 8 E. (Riley County, Kans.)
Pbam-3-R	Road cut	SW¼SE¼ sec. 5, T. 10 S., R. 7 E. (Riley County, Kans.)
Pbam-4-R	Road cut	SE¼NE¼ ssc. 7, T., 11 S., R. 8 E. (Riley County, Kans.)
Pbam-5-R	Stream bank	NW¼NE¼ ssc. 16, T., 9 S., R. 7 E. (Riley County, Kans.)

Description of the Insoluble Residues. The clay and fine silt residues obtained from the Middleburg limestone member display a color change from a light olive-gray (Pbam-2-R) through pale yellowish brown (Pbam-1-R) to yellowish gray (Pbam-4-R). This variation occurs in the southeastern portion of the area and has a south-westerly trend. Samples Pbam-1-R, Pbam-3-R, and Pbam-5-R trend northwesterly and are all pale yellowish-brown. This color arrangement of the samples is probably due to a common source of clastic materials, i.e., a shore line that had a northwesterly trend. This interpretation is borne out by the color distribution in the southeastern portion of the area as the light-gray sediments, which are composed of heavier minerals, would be deposited closer to the shore. The average sample of Middleburg produced 6.6 percent by weight and 12.2 percent by volume of fine residue (Figs. 5a and 5b).

Fine unmodified, loose to aggregated, euhedral quartz grains are a prominent coarse residue constituent in all samples (Fig. 5c). Beekite, as defined in this report, is the most diagnostic residue of the Middleburg and is composed of abundant ostracods of the genus Hollinella and some of the genus Cavellina (Figs. 5c). Foraminifers, similar to the genus Dentalina, were also found. Spongy clay showing limonitic stain composes more than 10 percent by volume of sample Pbam-3-R and lesser amounts are evident in samples Pbam-2-R and Pbam-5-R (Fig. 5). Traces of tubular silica were found in all samples and a trace of gilsonite was found in sample Pbam-1-R. The coarse residue constitutes an average of 0.3 percent by weight and 0.9 percent by volume of the samples (Figs. 5a and 5b).

Stratigraphic Correlation by the Use of Insoluble Residues. Beekite, composed mainly of ostracods, and the relatively high percentage of quartz are diagnostic coarse residues of the Middleburg limestone member in the

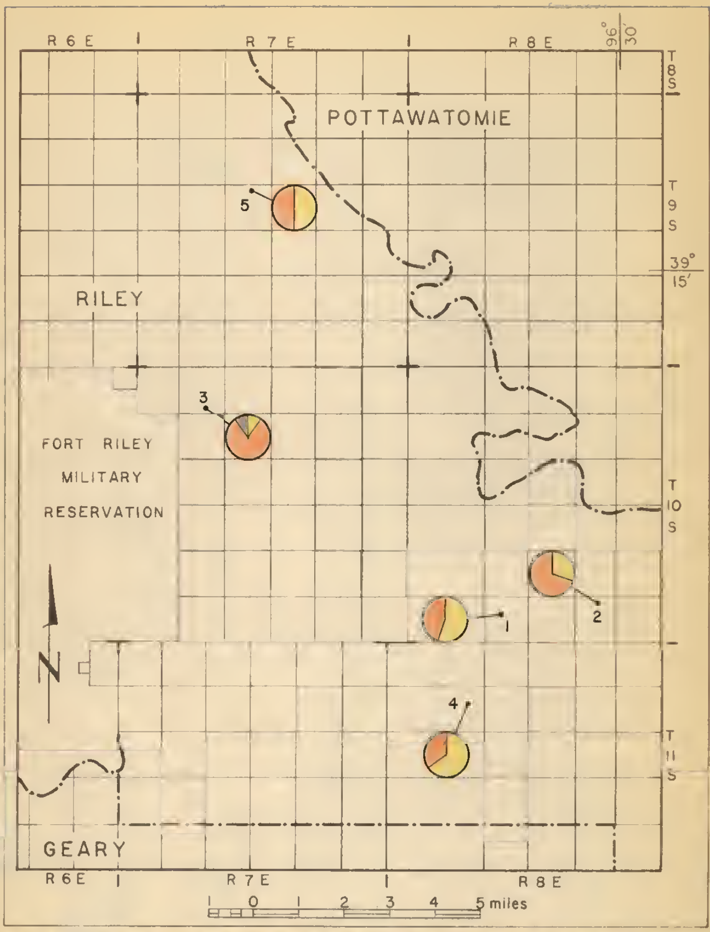

Fig. 5. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the Middleburg limestone member of the Bader limestone.

Sample number	Location	Sample weight (gram)	Residue						
			Coarse			Fine			
			Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
Pbam-1-R	SE¼NW¼ sec. 32, T. 10 S., R. 8 E. Hillside outcrop	56.4	0.1	0.2	1.0	0.7	1.2	2.0	10 YR 6/2
Pbam-2-R	NW¼NE¼ sec. 33, T. 10 S., R. 8 E. Road cut	59.3	0.2	0.3	1.5	5.6	9.4	17.0	5 Y 6/1
Pbam-3-R	SW¼SE¼ sec. 5, T. 10 S., R. 7 E. Road cut	60.0	0.2	0.3	1.0	4.5	7.5	15.0	10 YR 6/2
Pbam-4-R	SE¼NE¼ sec. 7, T. 11 S., R. 8 E. Road cut	59.7	0.1	0.2	0.5	4.5	7.5	14.0	5 Y 7/2
Pbam-5-R	NW¼NE¼ sec. 16, T. 9 S., R. 7 E. Stream bank	59.8	0.2	0.3	0.5	4.6	7.7	13.0	10 YR 6/2
Average	- - - - - - - - - - - - - - - -	59.1	0.2	0.3	0.9	4.0	6.6	12.2	- - - -

Fig. 5a. Sample data for the Middleburg limestone member of the Bader limestone.

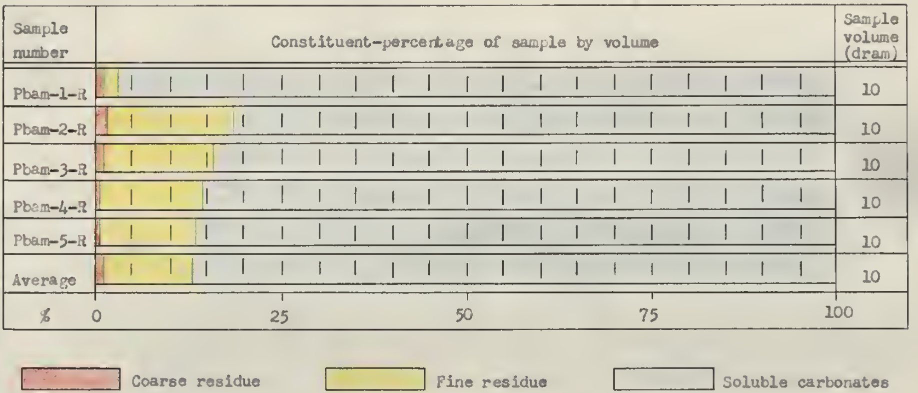

Fig. 5b. Constituent-percentage of sample by volume from the Middleburg limestone member of the Bader limestone.

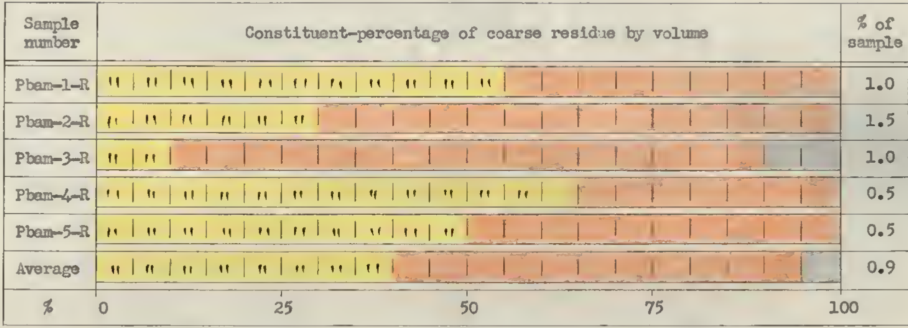

Fig. 5c. Constituent-percentage of coarse residue by volume from the Middleburg limestone member of the Bader limestone.

area inveetigated ae shown by the circlegrams in Fig. 5. Poeitive stratigraphic correlation would be possible by using these residuee, but the limonitic reeidues of the overlying Crouse limestons and the tubular eilica of the underlying Eiss limestons member would be of aid, aleo, in logging well eamplee.

Eiss Limeetone Member of the Bader Limeetone

<u>Description of the Member</u>. The Eies limeetone member usually consiets of two or more limestones separated by shale partinge. The limestonee are hard and maseive but weather blocky or porous, and are gray to tan gray. The intervening shalee are thin bedded, clayey to eilty, calcareoue, and usually tan or tan gray. Pelecypods, brachiopods, echinoid epinee, and crinoid columnale are the foesile common in the limeetone layers. The average thicknees of this member ie about 5 feet and it forms a prominent hillside bench, which is ueually covered with weathered, porous, equare blocke, about 30 fest above the Cottomwood limeetone member of the Beattie limestone.

The etratigraphic relationehip of the Eise limeetone member with the other units of the Council Grove Group is shown in Fig. 2.

<u>Regieter of Sampled Localities</u>. Outcrops of ths Eiss limeetone member were eampled at the following five locations:

Sample Number	Type of Outcrop	Legal Description
Pbae-1-R	Hilleide	$SE\frac{1}{4}NW\frac{1}{4}$ sec. 32, T. 10 S., R. 8 E. (Riley County, Kane.)
Pbae-2-R	Road cut	$NW\frac{1}{4}NE\frac{1}{4}$ sec. 34, T. 10 S., R. 8 E. (Riley County, Kane.)
Pbae-3-R	Road cut	$SW\frac{1}{4}SE\frac{1}{4}$ eec. 5, T. 10 S., R. 7 E. (Riley County, Kans.)
Pbae-4-R	Road cut	$SE\frac{1}{4}NE\frac{1}{4}$ sec. 7, T. 11 S., R. 8 E. (Riley County, Kans.)

Sample Number	Type of Outcrop	Legal Description
Pbae-5-R	Stream bank	N ¼ NE ¼ sec. 16, T. 9 S., R. 7 E. (Riley County, Kans.)

Description of the Insoluble Residues. The Eiss limestone member produces a fine residue which is predominantly yellowish-gray; only in sample Pbae-1-R does the color change to light brown (Fig. 6a). The average percentage of sample by weight of fine residue is 3.1 but the percentage of sample by volume is 10.9 (Figs. 6a and 6b).

Tubular silica is the predominant coarse residue constituent in all samples but Pbae-1-R (Fig. 6c). These "worm casts" appeared as loosely aggregated masses of light-gray color. Beekite, in the form of spongy to mottled ostracods, and bryozoan and brachiopod fragments, is also an important residue; it is found in all samples and averages 30 percent by volume (Fig. 6c). Red to white celestite was found in the three western-most samples but is an important constituent only in sample Pbae-4-R (Fig. 6c). Zircon, gilsonite and limonite were found as minor traces in the south-eastern samples (Fig. 6). The coarse residues constitute an average of 0.5 percent by weight and 1.6 percent by volume of ths samples (Figs. 6a and 6b).

Stratigraphic Correlation by the Use of Insoluble Residues. Areal correlation of the Eiss limestone member would be doubtful if based solely upon the residues obtained from it inasmuch as the ratio of tubular silica to beekite is not constant enough to make positive identification (Fig. 6). These same residues occur in other limestones of this group. However, in logging well samples identification could be made by comparing the residues from the overlying and underlying limestone members with those of the Eiss if the position in the stratigraphic column of each limestone member is considered. As has been mentioned, the overlying Middleburg limestone member

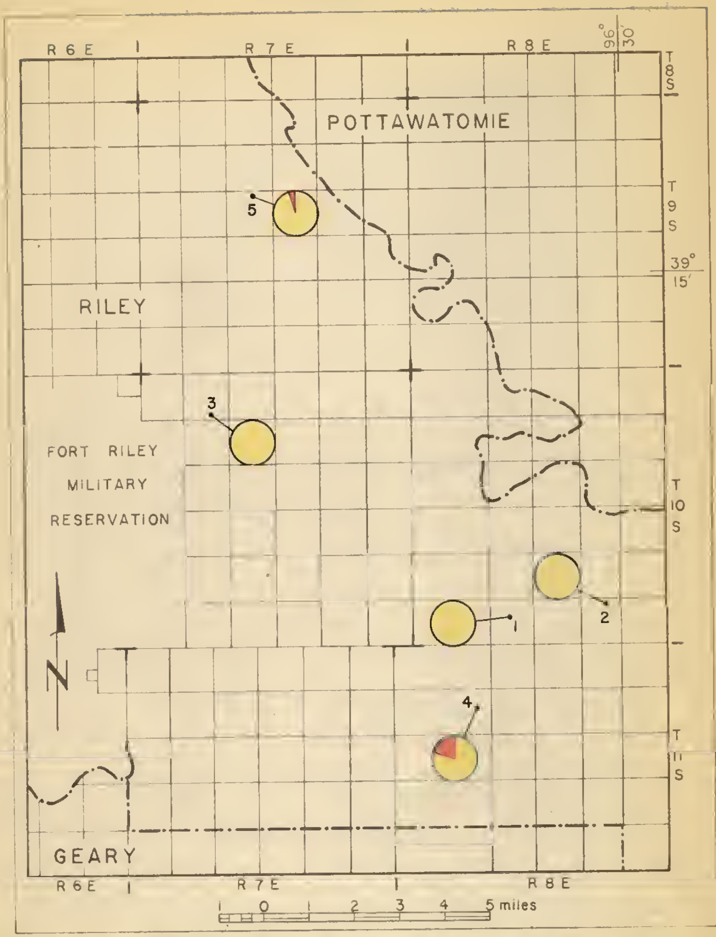

Fig. 6. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the Eiss limestone member of the Bader limestòne.

Sample number	Location	Sample weight (gram)	Residue						
			Coarse			Fine			
			Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
Pbae-1-R	SE¼NW¼ sec. 32, T. 10 S., R. 8 E. Hillside outcrop	60.2	0.1	0.2	0.5	0.7	1.2	2.0	5 YR 6/4
Pbae-2-R	NW¼NE¼ sec. 34, T. 10 S., R. 8 E. Road cut	59.0	0.6	1.0	3.0	3.6	6.1	13.0	5 Y 7/2
Pbae-3-R	SW¼SE¼ sec. 5, T. 10 S., R. 7 E. Road cut	61.5	0.2	0.3	1.5	4.2	6.8	13.5	5 Y 7/2
Pbae-4-R	SE¼NE¼ sec. 7, T. 11 S., R. 8 E. Road cut	59.8	0.3	0.5	1.5	3.5	5.9	14.0	5 Y 7/2
Pbae-5-R	NW¼NE¼ sec. 16, T. 9 S., R. 7 E. Stream bank	58.7	0.3	0.5	1.5	3.4	5.8	12.0	5 Y 7/2
Average	- - - - - - - - - - - - - - - - -	59.8	0.3	0.5	1.6	3.1	5.2	10.9	- - - - -

Fig. 6a. Sample data for the Eiss limestone member of the Bader limestone.

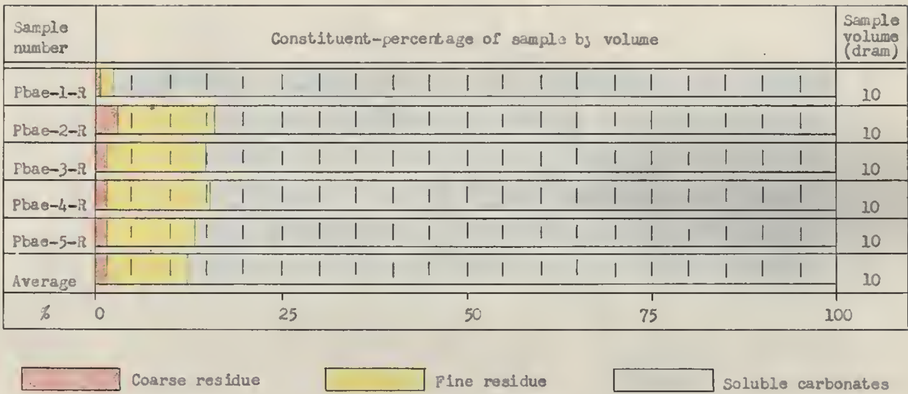

Fig. 6b. Constituent-percentage of sample by volume from the Eiss limestone member of the Bader limestone.

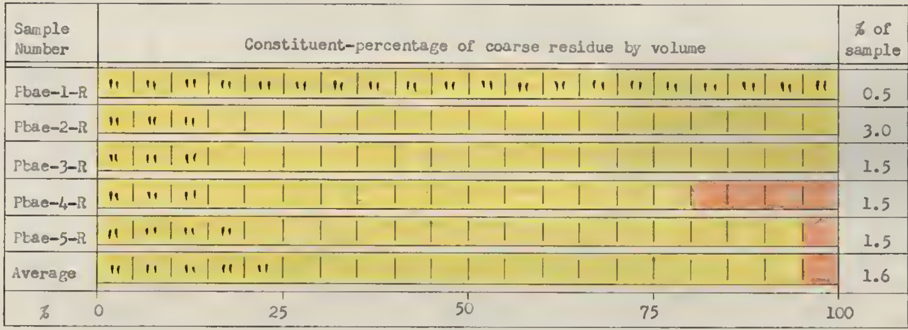

Fig. 6c. Constituent-percentage of coarse residue by volume from the Eiss limestone member of the Bader limestone.

contains ostracod beekite plus abundant loose quartz grains as the diagnostic residues (Fig. 5). The underlying Morrill limestone member of the Beattie Limestone has nearly all red celestite or yellowish-brown to yellowish-orange tubular silica as the predominating residues (Fig. 7). It is believed that only by this sequence association can accurate correlation be accomplished when using only residues. The residues that are characteristic of the Eise are also prominent in the Neva limestone member of the Grenola Limestone (Fig. 9c).

Morrill Limestone Member of the Beattie Limestone

Description of the Member. The Morrill limestone member is slightly argillaceous, varies greatly in hardness, and is brownish to gray orange but weathers tan. The limestone is massive in a fresh exposure but becomes quite porous and irregular when weathered. There were no fossils observed in this member but celestite fragments were abundant in several exposures. Its average thickness is about 2 feet.

The stratigraphic relationship of the Morrill limestone member with the other units of the Council Grove Group is shown in Fig. 2.

Register of Sampled Localities. Samples were collected from the Morrill limestone member at the five following locations:

Sample Number	Type of Outcrop	Legal Description
Pbem-1-R	Hillside	SE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 32, T. 10 S., R. 8 E. (Riley County, Kans.)
Pbem-2-R	Road cut	NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 34, T. 10 S., R. 8 E. (Riley County, Kans.)
Pbem-3-R	Road cut	NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 26, T. 10 S., R. 7 E. (Riley County, Kans.)
Pbem-4-R	Road cut	SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 29, T. 10 S., R. 8 E. (Riley County, Kans.)

Sample Number	Type of Outcrop	Legal Description
Pbem-5-R	Quarry	SE¼NW¼ sec. 10, T. 9 S., R. 7 E. (Riley County, Kans.)

Description of the Insoluble Residues. The clay and fine silt obtained as fine residues from the Morrill limestone member display little continuity of color for each sample color is different (Fig. 7a). Gray is the predominating color in the south-east portion of the area while various shades of orange and brown are the colors found in the central and northern parts of the area (Fig. 7). This irregular color distribution is thought to be due to the relative thinness of the parent rock. The underlying Florena shale member of the Beattie limestone is a thin shale when compared with others of the Council Grove Group. The Stearns shale, which overlies the Morrill, is much thicker than the Florena and toward the south, in Lyon and Morris Counties the Stearns locally contains a thin coal bed; thus displaying an interval of environmental instability during the time of deposition of this portion of the Council Grove Group. The lack of uniformity in deposition during this time is illustrated in the Morrill by its local variations in color, thickness, and lithology. The average percentage of sample by weight of fine residue is 5.7 whereas the percentage of sample by volume is 10.2 (Figs. 7a and 7b).

Crystalline to amorphous, white to red celestite comprises 80 percent or more of the coarse residue constituent of samples Pbem-2-R, Pbem-3-R and Pbem-5-R (Fig. 7c). The celsetite found in the Long Creek limestone member of the Foraker limestone could not be distinguished from that of the Morrill. Chert, in the form of aggregated tubular silica, composes 85 percent or more of the coarse residues from samples Pbem-1-R and Pbem-4-R (Fig. 7c). Only in sample Pbem-1-R is there any fine spongy chert. Strong traces of massive

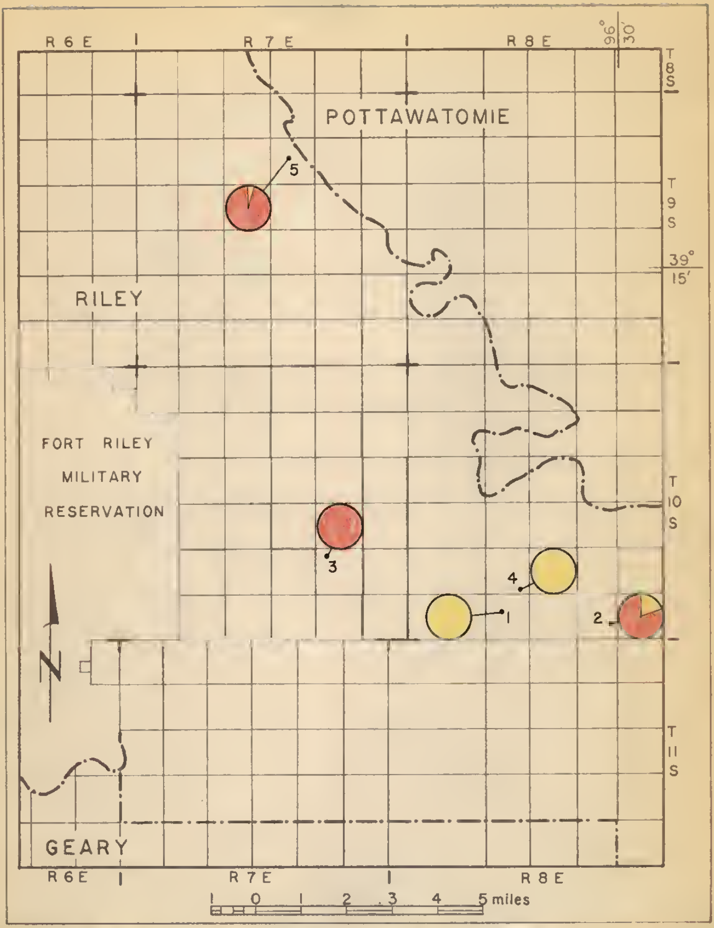

Fig. 7. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the Morrill limestone member of the Beattie limestone.

Sample number	Location	Sample weight (gram)	Residue						
			Coarse			Fine			
			Weight (gram)	% weight	% volume	weight (gram)	% weight	% volume	Color number
Pbem-1-R	SE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 32, T. 10 S., R. 8 E. Hillside outcrop	61.3	0.1	0.2	0.5	3.7	5.9	11.0	10 YR 6/6
Pbem-2-R	NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 34, T. 10 S., R. 8 E. Road cut	61.5	0.1	0.2	0.5	3.4	5.5	11.0	5 Y 7/2
Pbem-3-R	NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 26, T. 10 S., R. 7 E. Road cut	59.0	3.5	5.9	9.0	0.8	1.4	2.0	10 YR 5/4
Pbem-4-R	SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 29, T. 10 S., R. 8 E. Road cut	54.4	0.1	0.2	0.5	5.5	10.1	15.0	5 Y 6/1
Pbem-5-R	SE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 10, T. 9 S., R. 7 E. Quarry	60.7	1.1	1.8	3.0	3.5	5.8	12.0	10 YR 7/4
Average	- - - - - - - - - - - - - - - - -	59.4	1.0	1.7	2.7	3.5	5.7	10.2	- - - - -

Fig. 7a. Sample data for the Morrill limestone member of the Beattie limestone.

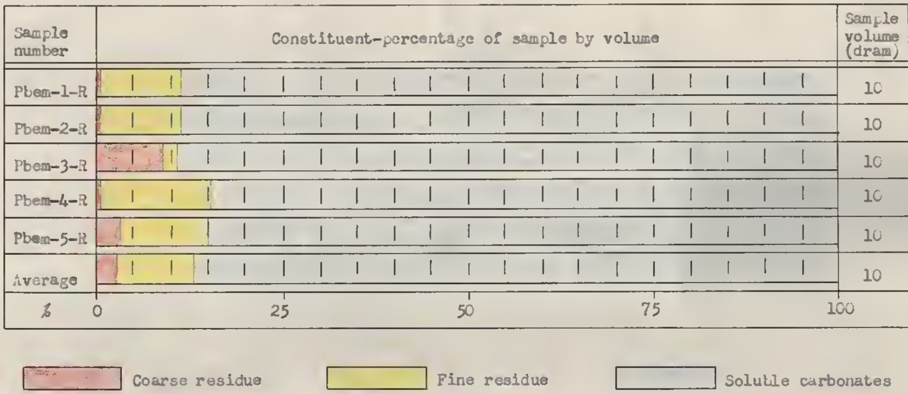

Fig. 7b. Constituent-percentage of sample by volume from the Morrill limestone member of the Beattie limestone.

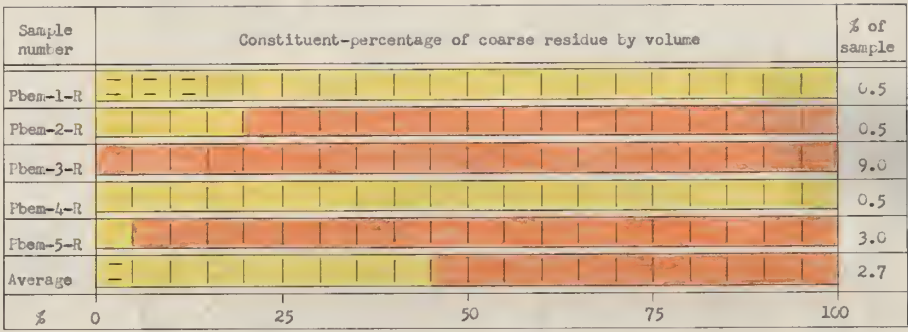

Fig. 7c. Constituent-percentage of coarse residue by volume from the Morrill limestone member of the Beattie limestone.

gypsum and limonite were found in all samples. The presence of limonite may account for the predominating orange and brown colors of the fine residues, Zircon and gilsonite are minor constituents of sample Pbem-4-R. The coarse residues constitute an average of 1.7 percent by weight and 2.7 percent by volume of sample (Figs. 7a and 7b).

Stratigraphic Correlation by the Use of Insoluble Residues. Correlation of the Morrill limestone member on the basis of residues obtained from it would be inaccurate. Positive recognition of the Morrill would be possible if it is taken into consideration that it is the only limestone above the Cottonwood limestone member of the Beattie limestone that has either a high concentration of celestite or "worm casts" associated with strong traces of massive gypsum and limonite but totally lacking the beekite which is found in the Eiss limestone member (Figs. 6c and 7). Reference is made to the Cottonwood because it is without a doubt the best "key horizon" or "marker" limestone within the Council Grove Group. It contains a characteristic coarse residue found in no other limestone of this group (Fig. 8c).

Cottonwood Limestone Member of the Beattie Limestone

Description of the Member. The Cottonwood limestone member is a single massive layer with an argillaceous zone in its basal part. In most exposures this limestone weathers into four more or less distinct ledges. Two to four relatively thin lenses of chert nodules are usually present in the massive part of the limestone, particularly in the "B" and "C" zones. The limestone is gray and weathers tan gray. Fusulinids, such as Pseudofusulina emaciata, are abundant chiefly in the upper part of this member, and occasionaly solution channels are present. Brachiopods, bryozoans, echinoid spines, and crinoid columnals are other fossils observed in the Cottonwood.

The average thickness of this limestone is about 6 feet and the massive beds form the most prominent hillside bench in the area investigated. Its position on a hillside is usually marked by a heavy growth of bushes at the base of the limestone. The growth of brush, at its contact with the underlying Eskridge shale, is the result of the movement of subsurface water along fractures and lithologic contact planes.

The Cottonwood may be easily recognized in the field by its thickness, massiveness, chert nodules, fusulinids, and the associated "brush line."

The stratigraphic relationship of the Cottonwood limestone member with the other units of the Council Grove Group is shown in Fig. 2.

<u>Register of Sampled Localities</u>. Outcrops of the Cottonwood limestone member were sampled at the five following locations:

Sample Number	Type of Outcrop	Legal Description
Pbec-1-R	Hillside	SE¼NW¼ sec. 32, T. 10 S., R. 8 E. (Riley County, Kans.)
Pbec-2-R	Hillside	NW¼SE¼ sec. 7, T. 10 S., R. 8 E. (Riley County, Kans.)
Pbec-3-R	Road cut	SE¼SE¼ sec. 8, T. 10 S., R. 7 E. (Riley County, Kans.)
Pbec-4-G	Hillside	NW¼NE¼ sec. 27, T. 11 S., R. 7 E. (Geary County, Kans.)
Pbec-5-P	Hillside	SE¼NE¼ sec. 34, T. 8 S., R. 7 E. (Pottawatomie County, Kans.)

<u>Description of the Insoluble Residues</u>. The Cottonwood limestone member produces a fine residue that ranges from light olive gray to yellowish-gray from east to west within the area (Fig. 8a). If the theory advanced in the discussion of the Middleburg limestone member of the Bader Limestone is applied, the clastic material source was east of the sampled locations (Fig. 8). The average percentage of sample by weight of fine residue is 7.6 and

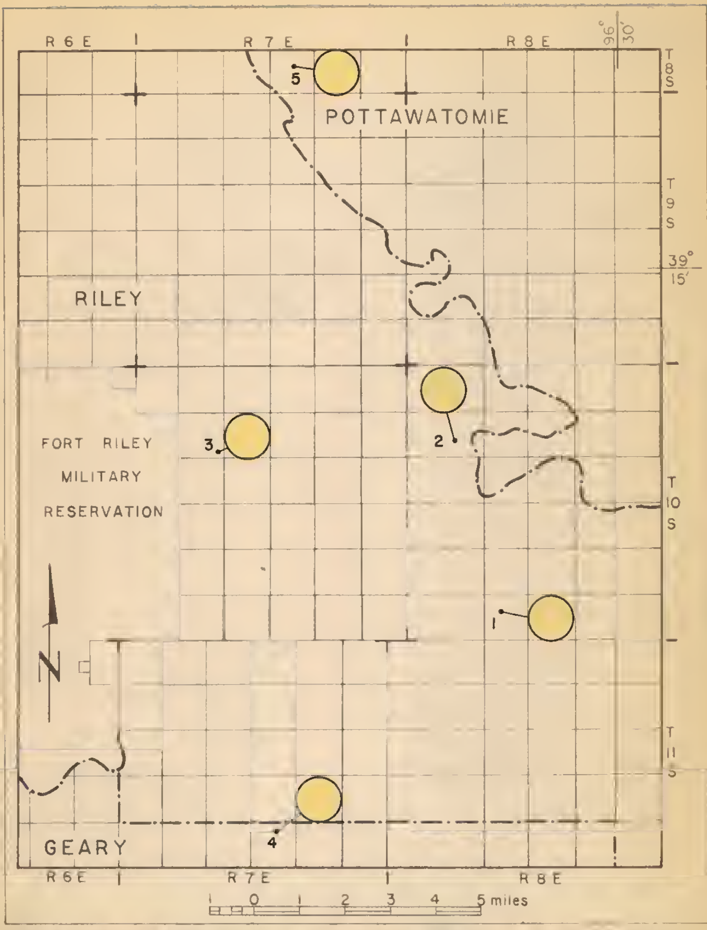

Fig. 8. Map of sampled sites with circlegrams showing the basic coarse residue constituent of the Cottonwood limestone member of the Beattie limestone.

Sample number	Location	Sample weight (gram)	Residue						
			Coarse			Fine			
			Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
Pbec-1-R	SE¼NW¼ sec. 32, T. 10 S., R. 8 E. Hillside outcrop	54.7	0.2	0.4	2.0	4.4	8.1	12.0	5 Y 6/1
Pbec-2-R	NW¼SE¼ sec. 7, T. 10 S., R. 8 E. Hillside outcrop	55.8	2.7	4.7	7.0	3.4	6.1	10.0	5 Y 7/1
Pbec-3-R	SE¼SE¼ sec. 8, T. 10 S., R. 7 E. Road cut	54.1	4.5	8.3	10.0	5.5	10.2	18.0	5 Y 7/2
Pbec-4-G	NW¼NE¼ sec. 27, T. 11 S., R. 7 E. Hillside outcrop	56.9	2.6	4.6	6.0	3.8	6.7	12.0	5 Y 7/2
Pbec-5-P	SE¼NE¼ sec. 34, T. 8 S., R. 7 E. Hillside outcrop	58.0	3.1	5.3	7.0	4.0	6.9	15.0	5 Y 7/2
Average	- - - - - - - - - - - - - - - - -	55.9	2.6	4.7	6.4	4.2	7.6	13.5	- - - -

Fig. 8a. Sample data for the Cottonwood limestone member of the Beattie limestone.

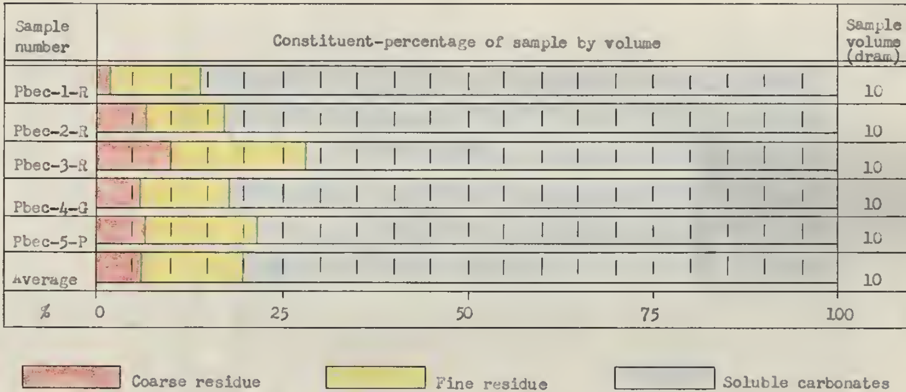

Fig. 8b. Constituent-percentage of sample by volume from the Cottonwood limestone member of the Beattie limestone.

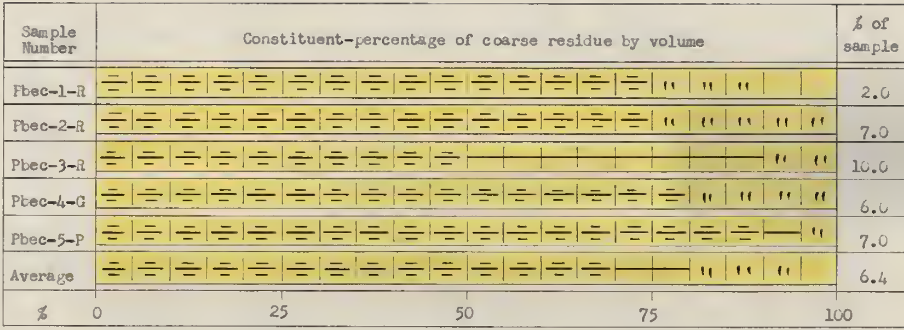

Fig. 8c. Constituent-percentage of coarse residue by volume from the Cottonwood limestone member of the Beattie limestone.

the percentage of sample by volume is 13.5 (Figs. 8a and 8b).

Spongy, chalky chert ranging in color from white to pale cream and containing abundant fusulinids (Pesudofusulina emaciata) is the predominant and diagnostic coarse residue of the Cottonwood limestone member (Fig. 8c). Although other limestones of the Council Grove Group contain fusulinids, only those of the Cottonwood are found in siliceous nodules. Chert, in the form of silicified fossil fragments of bryozoans, brachiopods, and echinoderms, makes a white chalky beekite that is a prominent residue of this limestone and is found in all samples observed (Fig. 8c). White, chalky, concentric oolitic chert containing fragments of bryozoans, brachiopods, and echinoderms is an important constituent in sample Pbec-1-R (Fig. 8). Smooth, chalcedonic, translucent chert, which ranges from white to pale pink and light gray, is a minor constituent in samples Pbec-3-R and Pbec-5-P but strong traces of it were found in all other samples (Fig. 8c). Tubular silica was observed in all samples and averages from 10 percent in the east to a trace in the west (Fig. 8). A trace of glauconite was found in sample Pbec-3-R while a small amount of red, silty material was present in sample Pbec-4-G. The coarse residue constitutes an average of 4.7 percent by weight and 6.4 percent by volume of original sample (Figs. 8a and 8b).

Stratigraphic Correlation by the Use of Insoluble Residues. Positive identification of the Cottonwood limestone member can be made through the use of the insoluble residues it contains. The spongy, chalky chert containing fusulinids is the characteristic residue that is easily identified as belonging to the Cottonwood and makes it the best "marker" limestone in this group of formations.

Neva Limestone Member of the Grenola Limestone

Description of the Member. The Neva Limestone member usually is composed of thick limestone interrupted by a shale bed approximately 3 feet thick near the base, but in some exposures other thin shales may occur in the middle and upper parts. In the upper part of this unit, the limestones are quite hard but become soft and honeycombed in the lower part. The interbedded shales are gray to dark gray. Echinoid spines are abundant in some zones and crinoid columnals, fusulinids, and brachiopods are other fossils commonly found in this member. *Lingula* and *Orbiculoidea* are the brachiopods present in the intervening shales. The average thickness of this member is about 16 feet, and the harder layers in the upper part form a prominent hillside bench.

The stratigraphic relationship of the Neva limestone member with the other units of the Council Grove Group is shown in Fig. 2.

Register of Sampled Localities. Samples were collected from exposures of the Neva limestone member at the five following locations:

Sample Number	Type of Outcrop	Legal Description
Pgn-1-R	Stream bank	SE¼NE¼ sec. 32, T. 10 S., R. 8 E. (Riley County, Kans.)
Pgn-2-R	Road cut	NE¼SE¼ sec. 7, T. 10 S., R. 8 E. (Riley County, Kans.)
Pgn-3-R	Road cut	NE¼NE¼ sec. 7, T. 11 S., R. 8 E. (Riley County, Kans.)
Pgn-4-R	Road cut	SE¼SW¼ sec. 10, T. 10 S., R. 7 E. (Riley County, Kans.)
Pgn-5-R	Road cut	NW¼SE¼ sec. 10, T. 9 S., R. 7 E. (Riley County, Kans.)

Description of the Insoluble Residues. The fine residues found in the Neva limestone member display a color range from light olive gray (Pgn-1-R)

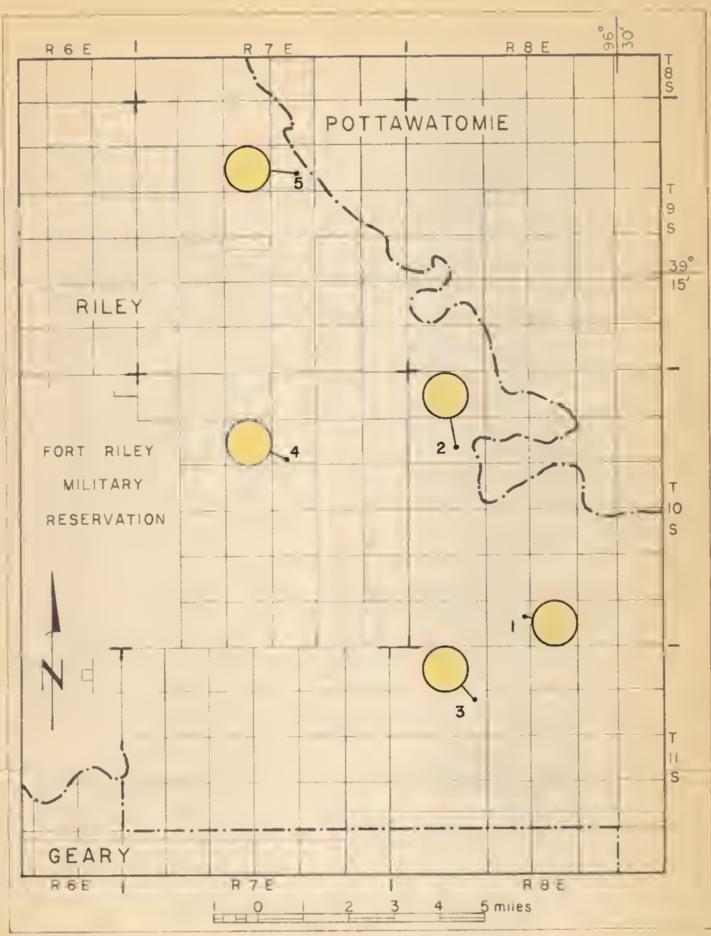

Fig. 9. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the Neva limestone member of the Grenola limestone.

Sample number	Location	Sample weight (gram)	Residue						
			Coarse			Fine			
			Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
Pgn-1-R	SE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 32, T. 10 S., R. 8 E. Stream bank	59.7	0.2	0.3	2.0	1.9	3.2	5.0	5 Y 6/1
Pgn-2-R	NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 7, T. 10 S., R. 8 E. Road cut	61.2	0.1	0.2	0.5	2.6	4.3	7.0	5 Y 8/1
Pgn-3-R	NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 7, T. 11 S., R. 8 E. Road cut	61.3	0.4	0.7	2.5	3.4	5.5	12.0	5 YR 7/2
Pgn-4-R	SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 10, T. 10 S., R. 7 E. Road cut	61.0	0.2	0.3	1.0	4.3	7.1	14.0	5 YR 7/2
Pgn-5-R	NW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 10, T. 9 S., R. 7 E. Road cut	59.6	0.4	0.7	2.0	3.1	5.2	11.0	5 YR 7/2
Average	- - - - - - - - - - - - - - - - -	60.6	0.3	0.4	1.6	3.1	5.1	9.8	- - - -

Fig. 9a. Sample data for the Neva limestone member of the Grenola limestone.

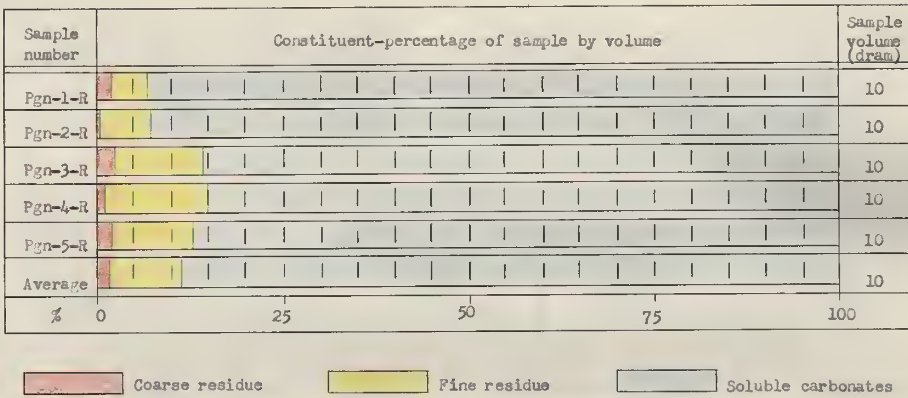

Fig. 9b. Constituent-percentage of sample by volume from the Neva limestone member of the Grenola limestone.

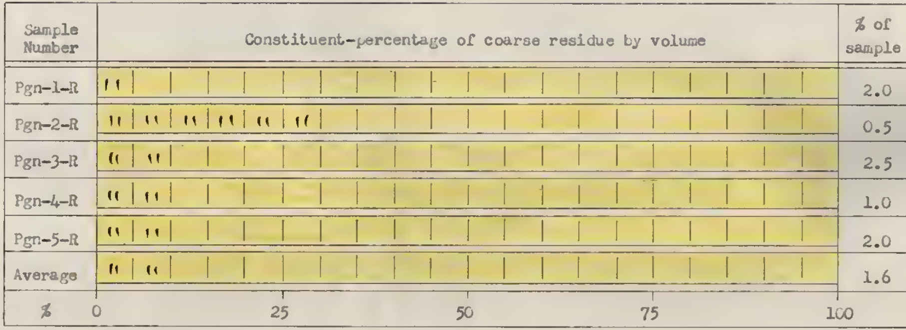

Fig. 9c. Constituent-percentage of coarse residue by volume from the Neva limestone member of the Grenola limestone.

through yellowish gray (Pgn-2-R) to grayish orange pink (Pgn-3-R, Pgn-4-R and Pgn-5-R) (Fig. 9). This agrees in part, at least, with the color distribution of the fine residues of the Cottonwood limestone and it is thought that this distribution ie also related to distance of deposition from the shore-line. The average percentage of eample by weight of fine residue is 3.1 but the percentage of sample by volume is 9.8 (Figs. 9a and 9b).

Light-gray tubular silica, similar to that observed in the Funston limestone and the Eiss limestone member is the predominating coarse residue of the Neva (Fig 9c). White to light gray beekite composed of bryozoan, brachiopod and echinoderm fragments ie also a common constituent (Fig. 9c). Minor traces of limonite, celestite, and massive, unmodified argillaceous material were found. The coarse residue constitutes an average of 0.4 percent by weight but 1.6 percent by volume of the original samples (Figs. 9a and 9b).

Stratigraphic Correlation by the Uee of Insoluble Residues. The major constituents, tubular eilica and beekite, are the eame as those of the Eise limestone member, but the ratio between the two ie greater and more consistent. However, the ratio of tubular silica to beekite (9:1) would be a poor aid in the correlation of this limestone if used alone (Fig. 9). Thie particular limestone illustrates why correlations should be based on the stratigraphic sequence, as well as the residue assemblages.

Burr Limestone Member of the Grenola Limestone

Description of the Member. The limestone of the Burr member is interrupted by a shale parting. The upper bed of limestone is finely granular to laminated, relatively soft, and about 4.5 feet thick. The lower limestone is hard, dense, massive, and is about 2 feet thick. The limestone is usually tan gray and weathers tan. The shale parting is clayey, usually calcareoue, gray to dark gray, and thin bedded. Echinoid spines, brachiopods, pelecypode, crinoid columnals, and micro-fossils were the fossils found in the limestone layere. The total thickness of the Burr is about 8 feet.

The etratigraphic relationship of the Burr limestone member with the othor units of the Council Grove Group is ehown in Fig. 2.

Register of Sampled Localities. Exposures of the Burr limestone member euitable for sampling were found at tho five following locations:

Sample Number	Type of Outcrop	Legal Description
Pgb-1-R	Road cut	SE¼NE¼ sec. 24, T. 10 S., R. 8 E. (Riley County, Kans.)
Pgb-2-R	Road cut	NE¼SE¼ sec. 7, T. 10 S., R. 8 E. (Riley County, Kans.)
Pgb-3-P	Road cut	SW¼SW¼ eec. 33, T. 9 S., R. 8 E. (Pottawatomie County, Kans.)
Pgb-4-R	Road cut	NE¼NE¼ eec. 7, T. 11 S., R. 8 E. (Riley County, Kans.)
Pgb-5-R	Stream bank	NE¼SW¼ sec. 10, T. 9 S., R. 7 E. (Riley County, Kans.)

Deecription of the Insoluble Residues. The Burr limestone member produces fine residues that range from light olive gray (samples Pgb-2-R, Pgb-3-P and Pgb-4-R) to yellowish gray (samples Pgb-1-R and Pgb-5-R). The yellowish gray color is probably due to limonitic staine because in samples Pgb-1-R and Pgb-5-R there ie about 5 percent of limonite present. The average percentage of fine residue by weight of sample is 8.8 but the percentage of fine reeidue by volume is 14.7 (Figs. 10a and 10b).

Light-gray tubular silica, 75 porcent or more, is present in all eamples (Fig. 10c). Fine-granular, mottled, tan chert and white concentric oolites are minor but important constituents of the coarse rosidues of each sample

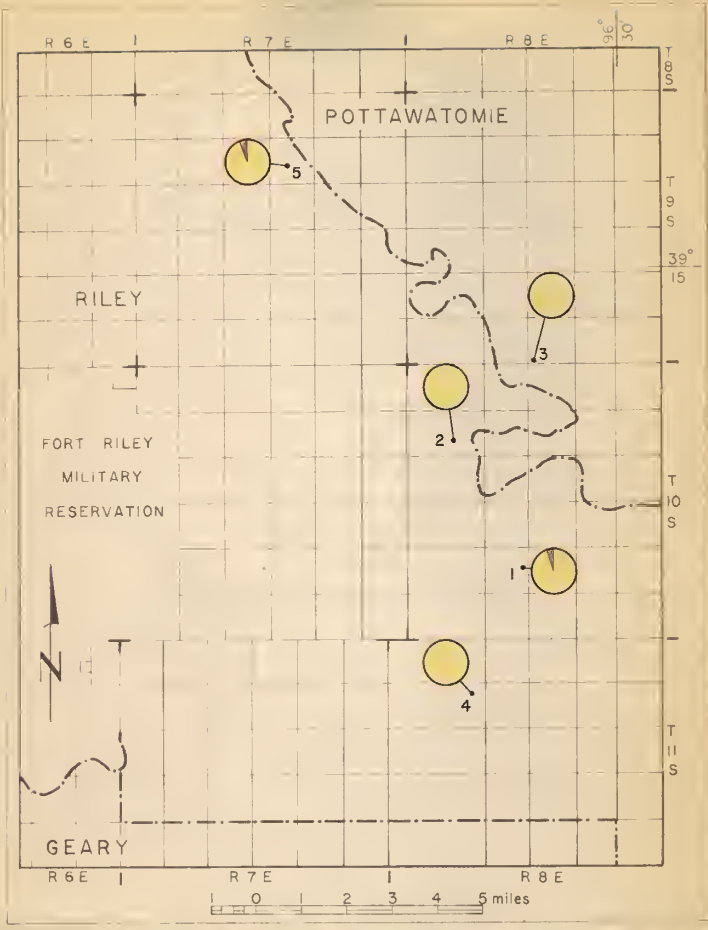

Fig. 10. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the Burr limestone member of the Grenola limestone.

Sample number	Location	Sample weight (gram)	Residue						
			Coarse			Fine			
			Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
Pgb-1-R	SE¼NE¼ sec. 24, T. 10 S., R. 8 E. Road cut	57.6	0.1	0.2	1.0	5.3	9.2	13.0	5 Y 7/2
Pgb-2-R	NE¼SE¼ sec. 7, T. 10 S., R. 8 E. Road cut	59.6	0.1	0.2	1.0	4.5	7.6	12.0	5 Y 6/1
Pgb-3-P	SW¼SW¼ sec. 33, T. 9 S., R. 8 E. Road cut	58.8	0.3	0.5	1.0	4.7	8.0	13.5	5 Y 6/1
Pgb-4-R	NE¼NE¼ sec. 7, T. 11 S., R. 8 E. Road cut	57.9	0.1	0.2	1.0	5.6	9.7	18.0	5 Y 6/1
Pgb-5-R	NE¼SW¼ sec. 10, T. 9 S., R. 7 E. Stream bank	59.6	0.2	0.3	1.0	5.6	9.4	17.0	5 Y 7/2
Average	- - - - - - - - - - - - - - - - -	58.7	0.2	0.3	1.0	5.1	8.8	14.7	- - - -

Fig. 10a. Sample data for the Burr limestone member of the Grenola limestone.

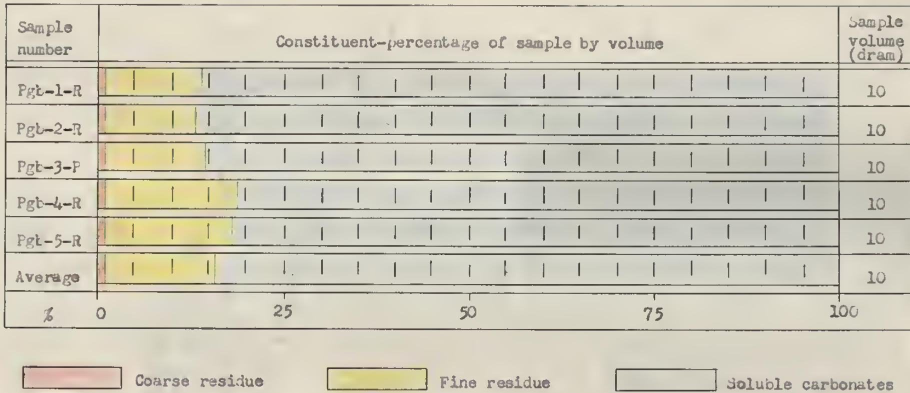

Fig. 10b. Constituent-percentage of sample by volume from the Burr limestone member of the Grenola limestone.

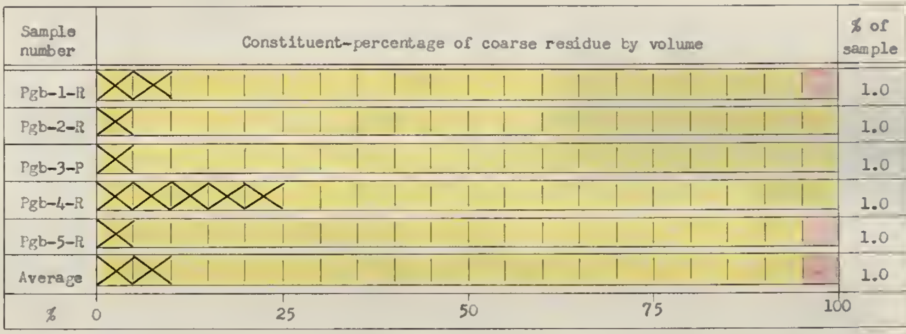

Fig. 10c. Constituent-percentage of coarse residue by volume from the Burr limestone member of the Grenola limestone.

(Fig. 10c). There is approximately 5 percent spongy limonite in samples Pgb-1-R and Pgb-5-R and strong traces of it in all other samples (Fig. 10). All samples also contain traces of loose anhedral to rounded, frosted, quartz grains. The coarse residues constitute an average of 0.3 percent by weight and 1.0 percent by volume of sample (Figs. 10a and 10b).

<u>Stratigraphic Correlation by the Use of Insoluble Residues</u>. All of the residues of the Burr must be considered when used as an aid to stratigraphic correlation. Except for the spongy limonite, the Burr limestone member residues are duplicated by those of the Glenrock limestone member of the Red Eagle Limestone; however, not all samples of the Glenrock show traces of rounded, frosted, quartz grains (Figs. 10c and 12c). It is the small quantity of spongy limonite that identifies the Burr and should be considered as its most diagnostic residue. Correlation of the Burr limestone through the use of residues is possible but not infallible unless the sequence of residue assemblages is considered.

Howe Limestone Member of the Red Eagle Limestone

<u>Description of the Member</u>. The Howe member is a tan to brown, massive, soft to hard limestone which weathers rotten and porous. Locally it appears to be sandy. It is heavily stained with limonite and, in most exposures, it usually has been stained by the maroon shales that overlie it. Ostracods and brachiopods are common fossils in some zones of this limestone. Its average thickness is about 4.2 feet.

The stratigraphic relationship of the Howe limestone member to the other units of the Council Grove Group is shown in Fig. 2.

<u>Register of Sampled Localities</u>. Exposures of the Howe limestone member were sampled at the five following locations:

Sample Number	Type of Outcrop	Legal Description
Prh-1-R	Hillside	NE¼NW¼ sec. 20, T. 10 S., R. 8 E. (Riley County, Kans.)
Prh-2-R	Road cut	NE¼SE¼ sec. 7, T. 10 S., R. 8 E. (Riley County, Kans.)
Prh-3-P	Road cut	SW¼SW¼ sec. 33, T. 9 S., R. 8 E. (Pottawatomie County, Kans.)
Prh-4-R	Road cut	NW¼NW¼ sec. 2, T. 11 S., R. 8 E. (Riley County, Kans.)
Prh-5-R	Stream bank	SE¼NW¼ sec. 12, T. 11 S., R. 7 E. (Riley County, Kans.)

Description of the Insoluble Residues. The fine residues obtained from the Howe limestone member show a color range from light brown (sample Prh-1-R) through light olive gray (sample Prh-2-R) to yellowish gray (samples Prh-3-P, Prh-4-R and Prh-5-R), (Fig. 11a). The Howe was probably a lagoonal deposit and thus reflects variations in lithology due to shifting currents. This conclusion is corroborated by the irregular color pattern of the fine residue and the haphazard arrangement of zircon and rounded, frosted, quartz grains found in the coarse residue. The average percentage of fine residue by weight of sample is 7.7 and the percentage of fine residue by volume is 15.6 (Figs. 11a and 11b).

Tubular silica is the predominant coarse residue constituent found in all samples but Prh-4-R (Fig. 11c). The "worm casts" are spongy aggregates of light-gray color except in sample Prh-1-R in which some are stained with limonite. Sample Prh-4-R is composed mostly of crystalline to amorphous, red to white celestite (Fig. 11c). Traces of similar celestite were found in samples Prh-2-R and Prh-5-R. Good traces of fibrous gypsum were found in all samples. Loose, rounded, frosted, quartz grains compose more than 5 percent by volume of sample Prh-3-P and traces of the same material were observed

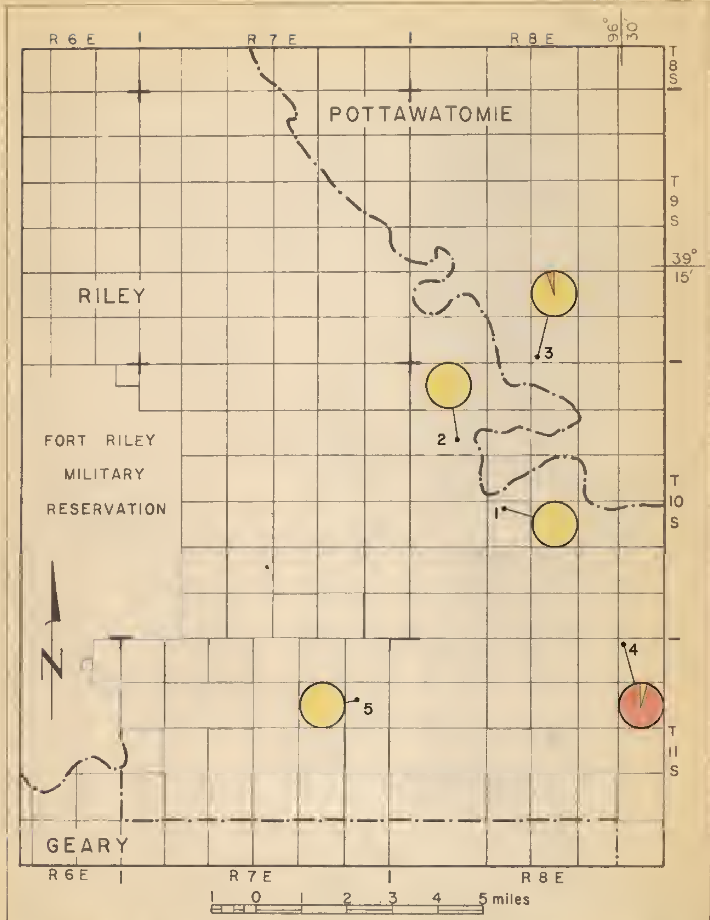

Fig. 11. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the Howe limestone member of the Red Eagle limestone.

Sample number	Location	Sample weight (gram)	Residue						
			Coarse			Fine			
			Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
Prh-1-R	NE¼NW¼ sec. 20, T. 10 S., R. 8 E. Hillside outcrop	58.0	0.1	0.2	T	2.7	4.7	10.0	5 YR 6/4
Prh-2-R	NE¼SE¼ sec. 7, T. 10 S., R. 8 E. Road cut	53.7	0.3	0.6	1.5	3.7	6.9	11.0	5 Y 6/1
Prh-3-R	SW¼SW¼ sec. 33, T. 9 S., R. 8 E. Road cut	59.9	0.1	0.2	T	5.0	8.3	17.0	5 Y 7/2
Prh-4-R	NW¼NW¼ sec. 2, T. 11 S., R. 8 E. Road cut	63.0	1.0	1.6	2.5	8.0	12.7	25.0	5 Y 7/2
Prh-5-R	SE¼NW¼ sec. 12, T. 11 S., R. 7 E. Stream bank	65.4	0.1	0.2	T	4.0	6.1	15.0	5 Y 7/2
Average	- - - - - - - - - - - - - - - - -	60.0	0.3	0.6	0.8	4.7	7.7	15.6	- - - -

Fig. 11a. Sample data for the Howe limestone member of the Red Eagle limestone.

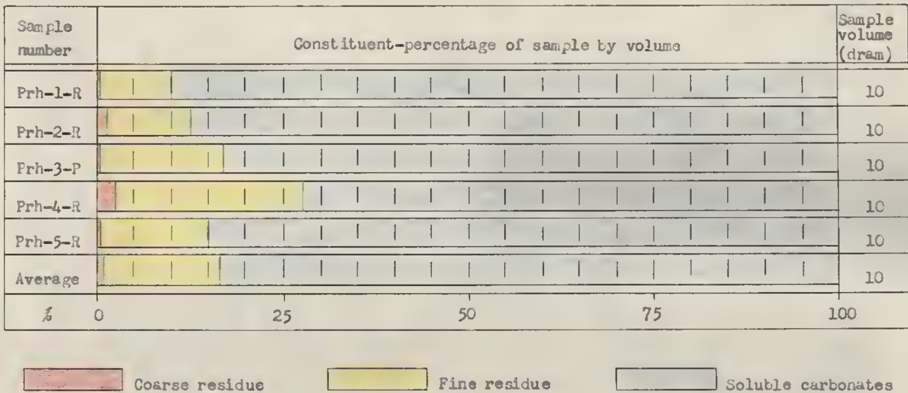

Fig. 11b. Constituent-percentage of sample by volume from the Howe limestone member of the Red Eagle limestone.

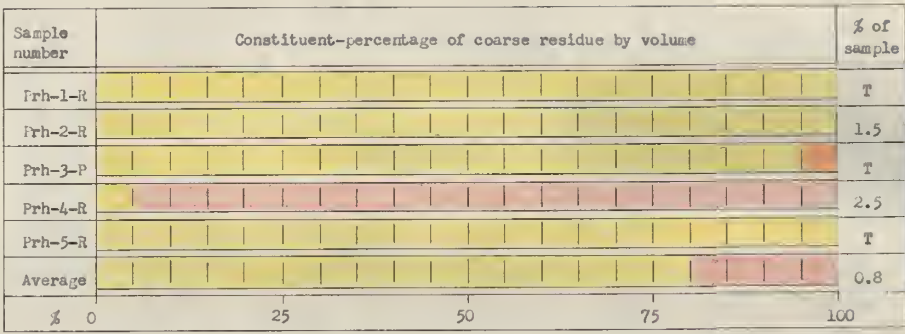

Fig. 11c. Constituent-percentage of coarse residue by volume from the Howe limestone member of the Red Eagle limestone.

in samples Prh-1-R and Prh-4-R (Fig. 11). Traces of zircon were found in samples Prh-3-P and Prh-5-R. Small particles of gilsonite were observed in sample Prh-1-R. The coarse residue constitutes an average of 0.6 percent by weight and 0.8 percent by volume of sample (Figs. 11a and 11b).

Stratigraphic Correlation by the Use of Insoluble Residues. Because of the lack of uniformity of its coarse residues, correlation of the Howe limestone member should not be attempted if based solely upon the contained residue assemblage. Local variations of the lithology of this limestone often make field identification rather difficult, thus stratigraphic position is about the most reliable basis for its correlation.

Glenrock Limestone Member of the Red Eagle Limestone

Description of the Member. The Glenrock member is a hard, massive, gray-brown limestone which usually weathers tan. Fusulinids are characteristic of it and are abundant in most exposures. Because this limestone is more resistant to weathering than the other members of the Red Eagle, it is the bench former of the formation. The average thickness of the Glenrock member is 1.5 feet.

Stratigraphic relationship of the Glenrock limestone member to the other units of the Council Grove Group is shown in Fig. 2.

Register of Sampled Localities. Samples were collected from the Glenrock limestone member at the five following locations:

Sample Number	Type of Outcrop	Legal Description
Prg-1-R	Hillside	NE¼NW¼ sec. 20, T. 10 S., R. 8 E. (Riley County, Kans.)
Prg-2-R	Road cut	NE¼SE¼ sec. 7, T. 10 S., R. 8 E. (Riley County, Kans.)

Sample Number	Type of Outcrop	Legal Description
Prg-3-P	Road cut	SW¼SW¼ sec. 33, T. 9 S., R. 8 E. (Pottawatomie County, Kans.)
Prg-4-R	Road cut	NE¼NW¼ sec. 2, T. 11 S., R. 8 E. (Riley County, Kans.)
Prg-5-R	Hillside	SW¼SW¼ sec. 32, T. 10 S., R. 8 E. (Riley County, Kans.)

Description of the Insoluble Residues. The Glenrock limestone member produces fine residues that show a color range from light olive gray (sample Prg-1-R) through pale yellowish brown (sample Prg-2-R) to grayish orange pink (samples Prg-3-P, Prg-4-R, and Prg-5-R), (Fig. 12a). This is the thinnest limestone studied and the irregular color pattern may be explained as it was in the discussion of the Morrill limestone member. The average percentage of fine residue by weight of sample is 6.1 and the percentage of fine residue by volume is 11.4 (Figs. 12a and 12b).

The coarse residues of the Glenrock are dominated by aggregates of light-gray tubular silica which compose 90 percent or more of each sample (Fig. 12c). Mottled chert appears as a minor constituent in nearly all samples (Fig. 12) but is most abundant in Prg-4-R. Traces of rounded, frosted quartz grains were found in samples Prg-1-R and Prg-2-R. Fibrous gypsum was observed in sample Prg-4-R. The coarse residues constitute an average of 0.3 percent by weight and 0.8 percent by volume of sample (Figs. 12a and 12b).

Stratigraphic Correlation by the Use of Insoluble Residues. Insoluble residues would be a valuable aid in correlating this limestone, but they should not be relied upon entirely for its identification. Previous discussions have shown that the residues displayed in the Glenrock are not restricted to it but are present and in similar amounts in other limestones of the Council Grove Group. Stratigraphic position is the most reliable basis for

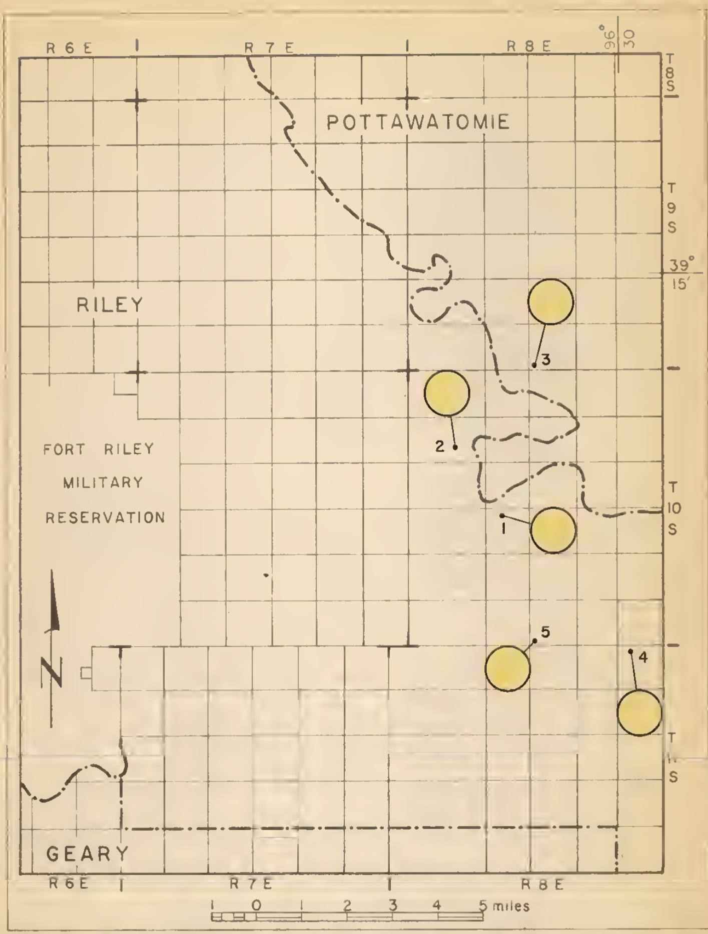

Fig. 12. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the Glenrock limestone member of the Red Eagle limestone.

Sample number	Location	Sample weight (gram)	Residue						
			Coarse			Fine			
			Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
Prg-1-R	NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 20, T. 10 S., R. 8 E. Hillside outcrop	59.4	0.2	0.3	1.0	4.6	7.7	13.0	5 Y 6/1
Prg-2-R	NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 7, T. 10 S., R. 8 E. Road cut	61.3	0.1	0.2	0.5	4.3	7.0	13.0	10 YR 6/2
Prg-3-F	SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 33, T. 9 S., R. 8 E. Road cut	60.2	0.3	0.5	1.0	4.1	6.8	14.0	5 YR 7/2
Prg-4-R	NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 2, T. 11 S., R. 8 E. Road cut	61.5	0.2	0.3	1.0	3.9	6.3	12.0	5 YR 7/2
Prg-5-R	SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 32, T. 10 S., R. 8 E. Hillside outcrop	58.8	0.1	0.2	0.5	1.5	2.6	5.0	5 YR 7/2
Average	- - - - - - - - - - - - - - - - -	60.2	0.2	0.3	0.8	3.7	6.1	11.4	- - - -

Fig. 12a. Sample data for the Glenrock limestone member of the Red Eagle limestone.

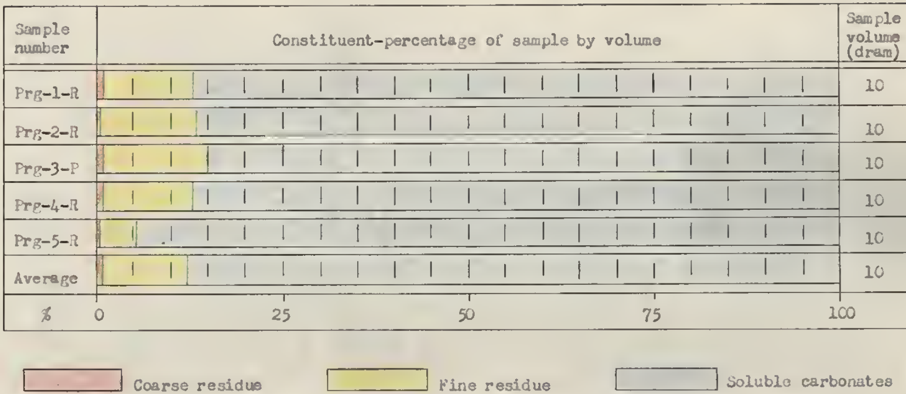

Fig. 12b. Constituent-percentage of sample by volume from the Glenrock limestone member of the Red Eagle limestone.

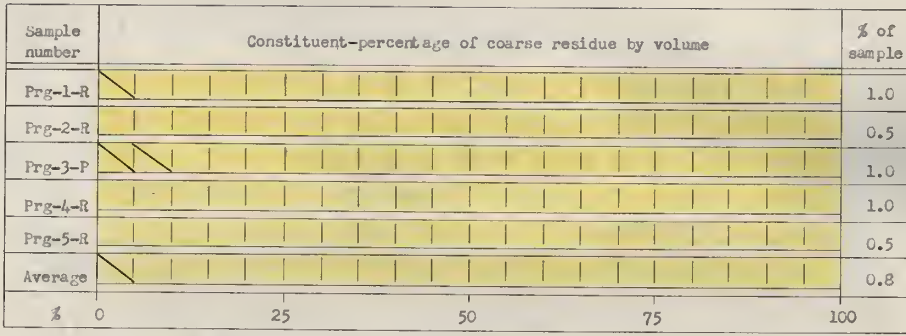

Fig. 12c. Constituent-percentage of coarse residue by volume from the Glenrock limestone member of the Red Eagle limestone.

the identification of the Glenrock.

Long Crssk Limestone Member of tho Foraker Limestons

Description of ths Member. The Long Creek membsr is a slightly dolomitic and soft limestone. It is massivs, fine grained, and usually contains several shale partings. The limestone layers are usually tan to gray orange but weather tan whereas ths shale partings are yellowish gray and thin bedded. Fossils are few or absent in this member. Its avsrage thickness is about 8.7 fset.

Ths stratigraphic relationship of ths Long Creek limestone member with the othsr units of the Council Grove Group is shown in Fig. 2.

Register of Sampled Localities. Outcrops of the Long Cresk limestone member wsre sampled at the fivs following locations:

Sample Number	Typs of Outcrop	Legal Description
Pf1-1-R	Road cut	NE¼NW¼ sec. 25, T. 10 S., R. 7 E. (Rilsy County, Kans.)
Pf1-2-R	Road cut	NE¼SE¼ ssc. 7, T. 10 S., R. 8 E. (Riley County, Kans.)
Pf1-3-P	Road cut	SW¼SW¼ sec. 33, T. 9 S., R. 8 E. (Pottawatomie County, Kans.)
Pf1-4-R	Stream bank	SE¼NW¼ sec. 12, T. 11 S., R. 7 E. (Riley County, Kans.)
Pf1-5-R	Road cut	NE¼NW¼ sec. 2, T. 11 S., R. 8 E. (Riley County, Kans.)

Description of ths Insoluble Residues. The fins residues from the Long Creek limestone member display a color gradation, east to west, from yellowish gray (samples Pf1-3-P and Pf1-5-R) through pale yellowish gray (samples Pf1-2-R) to light brown (samples Pf1-1-R and Pf1-4-R) (Fig. 13a). This color pattern is similar to that of several of the limestones discussed previously and is

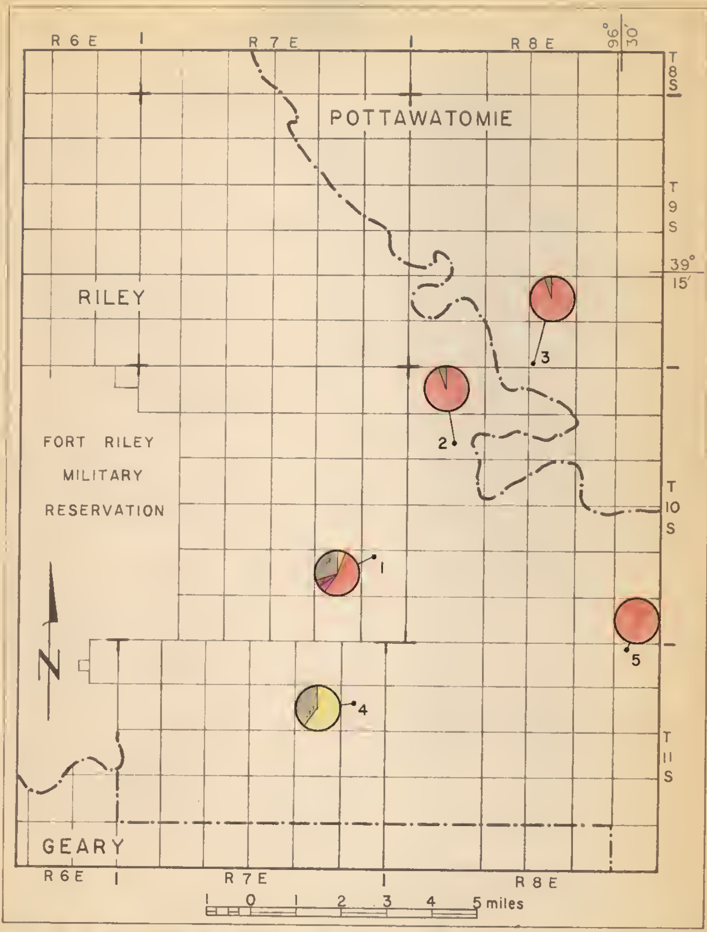

Fig. 13. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the Long-Creek limestone member of the Foraker limestone.

Sample number	Location	Sample weight (gram)	Residue						
			Coarse			Fine			
			weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
Pf1-1-R	$NE\frac{1}{4}NW\frac{1}{4}$ sec. 25, T. 10 S., R. 7 E. Road cut	58.0	1.2	2.7	3.0	5.1	8.8	16.0	5 YR 6/4
Pf1-2-R	$NE\frac{1}{4}SE\frac{1}{4}$ sec. 7, T. 10 S., R. 8 E. Road cut	55.4	3.0	5.4	7.0	5.6	10.1	18.0	10 YR 6/2
Pf1-3-P	$SW\frac{1}{4}SW\frac{1}{4}$ sec. 33, T. 9 S., R. 8 E. Road cut	56.4	1.9	3.4	4.0	6.8	12.0	24.0	5 Y 7/2
Pf1-4-R	$SE\frac{1}{4}NW\frac{1}{4}$ sec. 12, T. 11 S., R. 7 E. Stream bank	59.7	0.2	0.3	1.5	5.1	8.5	20.0	5 YR 6/4
Pf1-5-R	$NE\frac{1}{4}NW\frac{1}{4}$ sec. 2, T. 11 S., R. 8 E. Road cut	55.8	3.7	6.6	8.0	4.7	8.4	16.0	5 Y 7/2
Average	- - - - - - - - - - - - - - - - -	57.0	2.0	3.7	4.7	5.5	9.6	18.8	- - - -

Fig. 13a. Sample data for the Long Creek limestone member of the Foraker limestone.

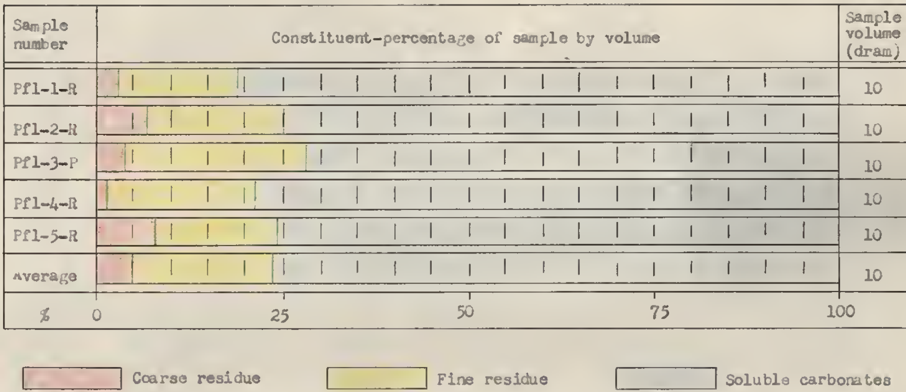

Fig. 13b. Constituent-percentage of sample by volume from the Long Creek limestone member of the Foraker limestone.

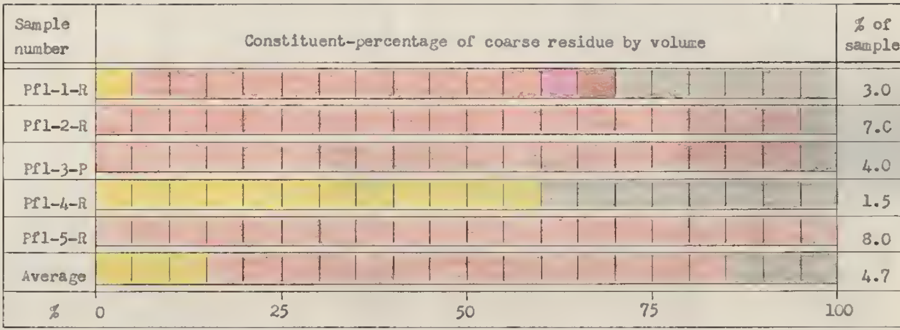

Fig. 13c. Constituent-percentage of coarse residue by volume from the Long Creek limestone member of the Foraker limestone.

thought to be the result of deposition of clastic sediments derived from farther east. The average sample of this limestone produced 9.6 percent by weight and 18.8 percent by volume of fine residues (Figs. 13a and 13b). This is the highest percentage of fine residue obtained from any of the limestones of the Council Grove Group.

White to red, crystalline to amorphous celestite is the most common mineral found in the coarse residues of the Long Creek limestone; however, it was lacking in sample Pf1-4-R (Fig. 13c). Poorly consolidated, micaceous, clayey, dark-gray silt was observed in all samples but was more abundant in the western samples (Fig. 13). This material is the most diagnostic constituent of the Long Creek residues. Tubular silica was also found in all samples and is the predominant residue in sample Pf1-4-R (Fig. 13c). Traces of limonite, selenitic gypsum, and mottled chert were recorded for most samples. The coarse residue constitutes an average of 3.7 percent by weight and 4.7 percent by volume of sample (Figs. 13a and 13b).

Stratigraphic Correlation by the Use of Insoluble Residues. Because of the diagnostic arenaceous material found in the Long Creek limestone member, it would be possible to identify this rock by the use of the insoluble residues it contains. The presence of abundant celestite and small amounts of "worm casts" would also be of aid in identification.

Americus Limestone Member of the Foraker Limestone

Description of the Member. The Americus member consists of two fossiliferous limestones separated by a black to dark-gray shale. Both limestones are hard, dense, and dark gray to blue gray. They are massive but weather blocky to platy. The shale parting commonly is carbonaceous, clayey, noncalcareous, and thin bedded to fissile. No fossil were observed in the shale parting, but crinoid columnals, echinoid spines, and brachiopods are the common fossils found in the limestones. The average thickness of this member is about 3 feet, and it is a good bench-forming limestone.

The stratigraphic relationship of the Americus limestone member with the other units of the Council Grove Group is shown in Fig. 2.

<u>Register of Sampled Localities.</u> Samples were collected from the Americus limestone member at the five following locations:

Sample Number	Type of Outcrop	Legal Description
Pfa-1-R	Stream bank	SE¼SE¼ sec. 26, T. 10 S., R. 8 E. (Riley County, Kans.)
Pfa-2-R	Railroad cut	NE¼SE¼ sec. 7, T. 10 S., R. 8 E. (Riley County, Kans.)
Pfa-3-P	Stream bank	SW¼SW¼ sec. 33, T. 9 S., R. 8 E. (Pottawatomie County, Kans.)
Pfa-4-P	Road cut	SW¼SW¼ sec. 34, T. 9 S., R. 8 E. (Pottawatomie County, Kans.)
Pfa-5-R	Stream bank	NE¼NW¼ sec. 20, T. 10 S., R. 8 E. (Riley County, Kans.)

<u>Description of the Insoluble Residues</u>. The fine residues found in the Americus limestone member are predominantly light olive gray but those of sample Pfa-1-R are pale yellowish brown (Fig. 14a). Outcrops of this limestone are limited within the area and it was difficult to obtain good samples over a wide area (Fig. 14). The average sample of this limestone produced 6.1 percent by weight and 12.0 percent by volume of fine residue (Figs. 14a and 14b).

Dark-gray aggregates of tubular silica are the predominating residue, 95 percent or more, in each sample of the Americus (Fig. 14c). In the Council Grove Group it is the only unit that yields dark-gray "worm casts". Samples Pfa-2-R and Pfa-3-P contain nearly 5 percent white, chalky, finely granular

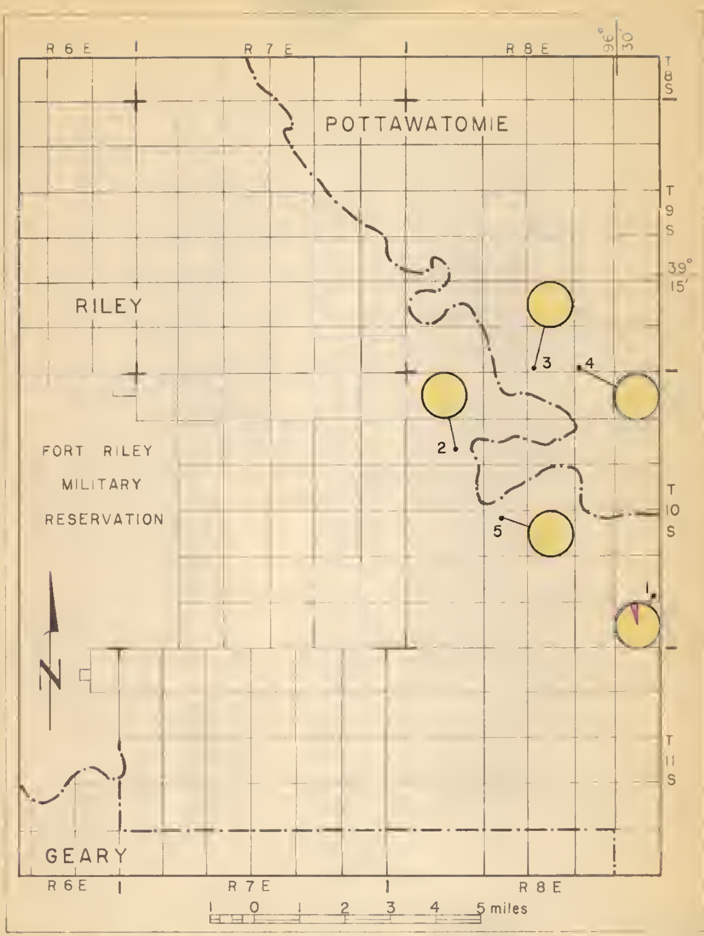

Fig. 14. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the Americus limestone member of the Foraker limestone.

Sample number	Location	Sample weight (gram)	Residue						
			Coarse			Fine			
			Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
Pfa-1-R	SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 26, T. 10 S., R. 8 E. Stream bank	63.4	1.0	1.6	3.0	4.3	6.8	13.0	10 YR 6/2
Pfa-2-R	NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 7, T. 10 S., R. 8 E. Railroad cut	61.8	1.0	1.6	5.0	4.5	7.3	12.0	5 Y 6/1
Pfa-3-P	SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 33, T. 9 S., R. 8 E. Stream bank	63.0	0.5	0.8	2.5	4.0	6.4	15.0	5 Y 6/1
Pfa-4-P	SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 34, T. 9 S., R. 8 E. Road cut	62.3	0.5	0.8	2.0	2.4	3.9	6.0	5 Y 6/1
Pfa-5-R	NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 20, T. 10 S., R. 8 E. Stream bank	63.8	1.0	1.6	4.5	4.0	6.3	14.0	5 Y 6/1
Average	- - - - - - - - - - - - - - - - -	62.8	0.8	1.3	3.4	3.8	6.1	12.0	- - - -

Fig. 14a. Sample data for the Americus limestone member of the Foraker limestone.

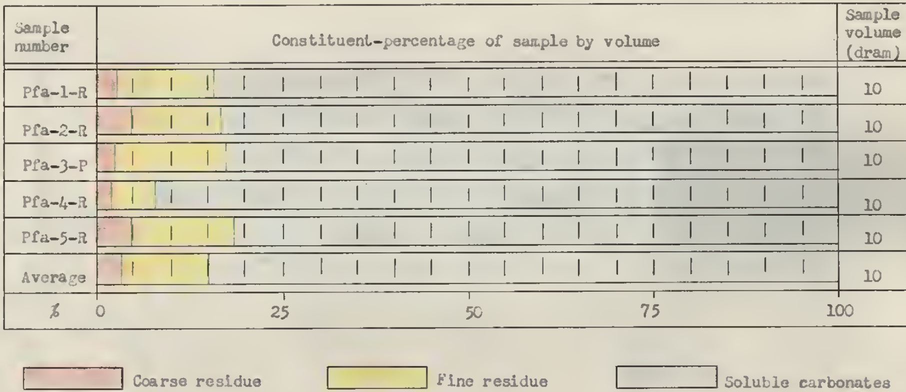

Fig. 14b. Constituent-percentage of sample by volume from the Americus limestone member of the Foraker limestone.

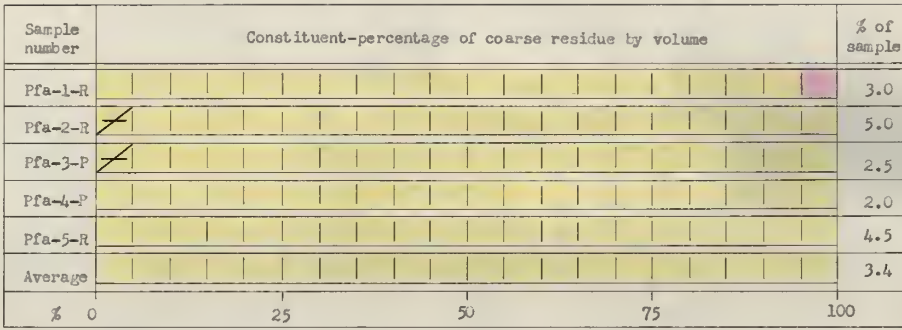

Fig. 14c. Constituent-percentage of coarse residue by volume from the Americus limestone member of the Foraker limestone.

chert that appears to be fragments of invertebrates but could not be positively identified as such. Traces of this chert were also found in all of the other samples. Fibrous gypsum composes approximately 5 percent of the volume of Pfa-1-R and traces of it were found in Pfa-2-R and Pfa-3-P (Fig. 14c). Traces of glauconite were recorded for samples Pfa-1-R and Pfa-4-P. The coarse residues constitute an average of 1.3 percent by weight and 3.4 percent by volume of sample (Figs. 14a and 14b).

Stratigraphic Correlation by the Use of Insoluble Residues. It would be possible to identify this rock by its persistently dark-gray tubular silica residues, and by the percentage volume of coarse residue.

ZONAL ANALYSIS OF THE COTTONWOOD LIMESTONE MEMBER OF THE BEATTIE LIMESTONE

Introduction

Because of the prominence of the Cottonwood limestone member in the Manhattan area, it was subjected to more intensive study than the other rocks of this group. This additional work was based upon the four "zones" in this rock that can be easily recognized in the field. Weathering characteristics, color, constituents and position were the criteria for field identification of these zones. The zones were arbitraily designated as A, B, C, and D, in decending order. Samples were obtained only from sites where all zones were exposed or easily uncovered. The procedure of obtaining and studying these samples was the same as that previously discussed.

The purpose of this additional investigation was two fold: 1) to interpret the sedimentary history of this limestone, and 2) to establish the basis for the laboratory identification of the zones. Because the fresh, unweathered rock chips from the different zones are hard to identify, it was postulated and later verified that recognition of zones within the Cottonwood limestone member could be based upon the included insoluble residue aseemblages.

Zone "A" of the Cottonwood Limestone Member. Lithology and Thicknese of the "A" Zone. This zone is a single massive layer eeparated from the underlying "B" zone by a thin argillaceous parting. In most hilleide outcrops of the Cottonwood limestone this zone has been removed by eroeion (Plate I, Fig. 2.). It is light gray and weathere dark gray and its surface is rather smooth as compared with those of the B and C zones. It ie in this zone that the fusulinids consistently appear to be most abundant. Echinoderm and brachiopod remains are aleo common. The average thicknese of the A zone is about 0.4 foot. (Fig. 15a).

Register of Sampled Localities. Exposures of the Cottonwood limestone member suitable for sampling were found at the 15 following locations (Fig. 15):

Sample Number	Type of Outcrop	Legal Description
A-1-R	Hilleide	$NW\frac{1}{4}SE\frac{1}{4}$ eec. 7, T. 10 S., R. 8 E. (Riley County, Kans.)
A-2-R	Hilleide	$NW\frac{1}{4}SE\frac{1}{4}$ eec. 23, T. 10 S., R. 7 E. (Riley County, Kans.)
A-3-R	Road cut	$SE\frac{1}{4}NE\frac{1}{4}$ sec. 34, T. 10 S., R. 8 E. (Riley County, Kans.)
A-4-R	Road cut	$NW\frac{1}{4}SE\frac{1}{4}$ sec. 14, T. 9 S., R. 7 E. (Riley County, Kane.)
A-5-R	Hillside	$NE\frac{1}{4}NE\frac{1}{4}$ sec. 36, T. 9 S., R. 7 E. (Riley County, Kans.)
A-6-R	Road cut	$SE\frac{1}{4}NE\frac{1}{4}$ eec. 23, T. 9 S., R. 7 E. (Riley County, Kane.)
A-7-R	Quarry	$SE\frac{1}{4}NE\frac{1}{4}$ sec. 20, T. 10 S., R. 8 E. (Riley County, Kans.)
A-8-R	Hillside	$NE\frac{1}{4}NE\frac{1}{4}$ sec. 14, T. 11 S., R. 8 E. (Riley County, Kans.)

Sample Number	Type of Outcrop	Legal Description
A-9-R	Hillside	SW¼NE¼ sec. 21, T. 11 S., R. 7 E. (Riley County, Kans.)
A-10-R	Hillside	SE¼NW¼ sec. 12, T. 11 S., R. 7 E. (Riley County, Kans.)
A-11-P	Road cut	SE¼SW¼ eec. 27, T. 9 S., R. 8 E. (Pottawatomie County, Kans.)
A-12-G	Hilleide	NW¼NE¼ eec. 27, T. 11 S., R. 7 E. (Geary County, Kans.)
A-13-P	Hillside	SE¼NE¼ sec. 34, T. 8 S., R. 7 E. (Pottawatomie County, Kans.)
A-14-R	Road cut	SE¼NE¼ eec. 7, T. 11 S., R. 8 E. (Riley County, Kans.)
A-15-R	Road cut	SE¼SE¼ eec. 8, T. 10 S., R. 7 E. (Riley County, Kans.)

Description of the Insoluble Residues. The fine residues in this zone are predominantly pale yellowish brown with the majority of the samples that are of thie color aligned toward the northwest. In the eastern and northeaetern parts of the area the clays and silte are brownish gray to light brownish bray, while in samples from the western part the sediments are grayish orange pink (Fig. 15a). Thie color pattern agrees with the theory previously mentioned that the source of clastic material was to the east or that this rock in the eastern part of thie area was deposited in a more brackish environment than that toward the west. The average zone "A" sample has 6.6 percent by weight and 9.0 percent by volume of fine residue (Figs. 15a and 15b).

The coarse residuee of the "A" zone are dominated by white opaque beekite composed mostly of echinoderm, brachiopod and molluecan fragments with the echinoid and crinoid remains being the most abundant (Fig. 15c). In the average sample, this material is about 80 percent by volume of the total

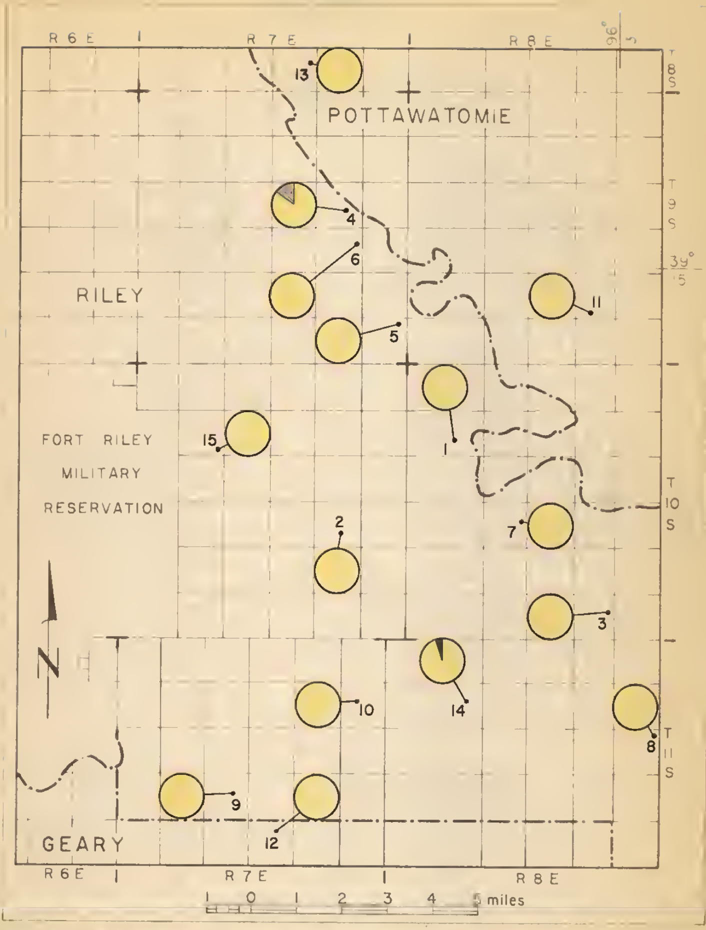

Fig. 15. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the "A" zone of the Cottonwood limestone member of the Beattie limestone.

Sample number	Location	Zone thick-ness	Sample weight (gram)	Residue						
				Coarse			Fine			
				Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
A-1-R	NW¼SE¼ sec. 7, T. 10 S., R. 8 E. Hillside outcrop	0.5	58.1	0.4	0.7	2.0	4.6	7.9	13.0	10 YR 6/2
A-2-R	NW¼SE¼ eec. 23, T. 10 S., R. 7 E. Hillside outcrop	0.3	56.5	0.7	1.2	2.0	3.7	6.6	8.0	5 YR 4/1
A-3-R	SE¼NE¼ sec. 34, T. 10 S., R. 8 E. Road cut	0.2	57.2	0.4	2.0	2.0	4.7	8.2	12.0	5 YR 6/1
A-4-R	NW¼SE¼ sec. 14, T. 9 S., R. 7 E. Road cut	0.4	55.1	0.3	0.5	2.0	3.6	6.5	4.0	10 YR 6/2
A-5-R	NE¼NE¼ sec. 36, T. 9 S., R. 7 E. Hillside outcrop	0.4	58.1	0.7	1.2	3.0	2.5	4.3	6.0	5 Y 7/2
A-6-R	SE¼NE¼ sec. 23, T. 9 S., R. 7 E. Road cut	0.4	58.8	0.3	0.5	2.0	2.5	4.2	7.0	10 YR 6/2
A-7-R	SE¼NE¼ sec. 20, T. 10 S., R. 8 E. Quarry	0.3	59.8	0.4	0.7	2.0	4.3	7.2	10.0	10 YR 6/2
A-8-R	NE¼NE¼ sec. 14. T. 11 S., R. 8 E. Hillside outcrop	0.2	55.0	1.2	2.2	4.0	3.4	6.2	8.0	10 YR 6/2

Fig. 15a. Sample data for the "A" zone of the Cottonwood limestone member of the Beattie limestone.

Sample number	Location	Zone thickness	Sample weight (gram)	Residue						
				Coarse			Fine			
				Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
A-9-R	SW¼NE¼ sec. 21, T. 11 S., R. 7 E. Hillside outcrop	0.3	59.1	0.5	0.8	2.0	4.4	7.4	11.0	5 YR 7/2
A-10-R	SE¼NW¼ sec. 12, T. 11 S., R. 7 E. Hillside outcrop	0.2	56.7	0.5	0.9	2.0	3.5	6.2	10.0	5 YR 6/1
A-11-P	SE¼SW¼ sec. 27, T. 9 S., R. 8 E. Road cut	0.3	58.2	0.6	0.9	2.0	3.5	6.0	11.0	5 YR 6/1
A-12-G	NW¼NE¼ sec. 27, T. 11 S., R. 7 E. Hillside outcrop	0.3	58.6	0.2	0.3	2.0	3.0	5.1	6.0	10 YR 6/2
A-13-P	SE¼NE¼ sec. 34, T. 8 S., R. 7 E. Hillside outcrop	0.3	57.7	0.3	0.4	2.0	2.3	6.0	7.0	5 YR 6/1
A-14-R	SE¼NE¼ sec. 7, T. 11 S., R. 8 E. Road cut	0.4	57.3	0.3	0.4	2.0	2.8	4.9	7.0	10 YR 6/2
A-15-R	SE¼SE¼ sec. 8, T. 10 S., R. 7 E. Road cut	1.1	49.5	1.0	2.0	3.0	7.1	14.3	20.0	5 YR 7/2
Average	- - - - - - - - - - - - - - - - - -	0.4	57.1	0.5	0.9	2.0	3.7	6.0	9.0	- - - -

Fig. 15a (contd). Sample data for the "A" zone of the Cottonwood limestone member of the Beattie limestone.

Fig. 15b. Constituent-percentage of sample by volume from the "A" zone of the Cottonwood limestone member of the Beattie limestone.

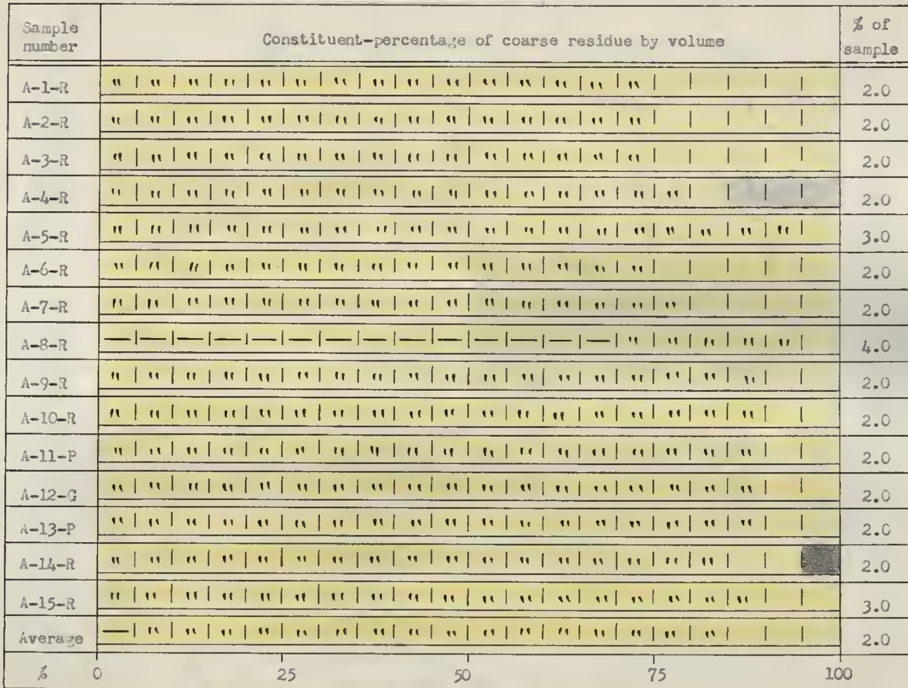

Fig. 15c. Constituent-percentage of coarse residue by volume from the "A" zone of the Cottonwood limestone member of the Beattie limestone.

coarse residue. Tubular silica was observed in all samples, but the average sample displays approximately 15 percent by volume of these silty appearing "siliceous worm casts". Chalky, white chert containing fusulinids was observed in samples A-5-R and A-8-R. Sample A-4-R contains appeoximately 15 percent by volume of tan, unmodified, micaceous clay as well as strong traces of magnetite and rounded, frosted quartz grains. Sample A-14-R also contains almost 5 percent of magnetite. The average sample of zone A contains 0.9 percent by weight and 2.0 percent by volume of coarse residues (Figs. 15a and 15b).

Stratigraphic Correlation and Zone Identification by the Use of Insoluble Residues. It would be extremely difficult to obtain from a test hole uncontaminated rock samples from the "A" or any zone of the Cottonwood, unless a core sample was taken. Because this situation does exist, only carefully obtained outcrop samples of any of the four zones could be used for correlation purposes. Zone identification would be a relatively simple task for the easily recognized and abundant white, opaque beekite fragments are diagnostic of the A zone.

Zone "B" of the Cottonwood Limestone Member. Lithology and Thickness of the "B" Zone. In the Flint Hills region this zone is usually a single massive layer that forms the upper part of most hillside outcrops of the Cottonwood limestone member. Locally it may be separated from the underlying "C" zone by a very thin argillaceous zone. Zone C is light gray and weathers tan-gray. In this area the B zone is rarely flinty but nodules of partly silicified material that weather more slowly than the rest of the rock give it a flinty appearance. This is also typical of the underlying C zone; however, the degree of roughness produced by differential weathering is not as great in zone B as that displayed in the C zone. Plate I, Fig. 2. Fusulinids are

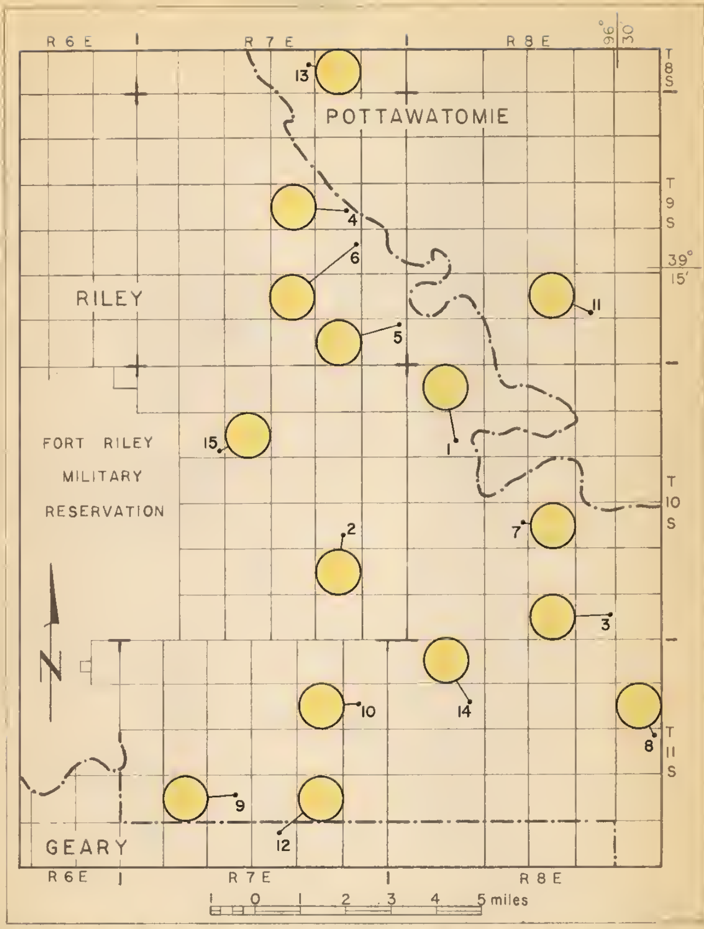

Fig. 16. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the "B" Zone of the Cottonwood limestone member of the Beattie limestone.

Sample number	Location	Zone thick-ness	Sample weight (gram)	Residue						
				Coarse			Fine			
				Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
B-1-R	NW¼SE¼ sec. 7, T. 10 S., R. 8 E. Hillside outcrop	2.5	55.8	3.7	6.6	10.0	3.3	5.9	8.0	10 YR 6/2
B-2-R	NW¼SE¼ sec. 23, T. 10 S., R. 7 E. Hillside outcrop	2.5	54.5	4.6	8.4	12.0	3.5	6.4	9.0	10 YR 6/2
B-3-R	SE¼NE¼ ssc. 34, T. 10 S., R. 8 E. Road cut	2.9	53.9	2.8	5.2	9.0	4.6	8.5	12.0	10 YR 6/2
B-4-R	NW¼SE¼ sec. 14, T. 9 S., R. 7 E. Road cut	3.0	46.6	3.1	6.7	18.0	2.3	4.9	6.0	5 YR 7/2
B-5-R	NE¼NE¼ sec. 36, T. 9 S., R. 7 E. Hillside outcrop	3.[illegible]	55.4	2.1	3.8	2.0	3.7	6.[illegible]	10.0	5 Y 6/4
B-6-R	SE¼NE¼ sec. 23, T. 9 S., R. 7 E. Road cut	3.0	51.7	3.4	6.6	11.0	3.3	6.4	9.0	5 YR 6/1
B-7-R	SE¼NE¼ sec. 20, T. 10 S., R. 8 E. Quarry	3.0	53.3	3.6	6.3	10.0	3.2	6.0	9.0	5 Y 7/2
B-8-R	NE¼NE¼ ssc. 14, T. 11 S., R. 8 E. Hillside outcrop	2.4	56.3	0.8	1.4	3.0	3.7	6.[illegible]	9.0	10 YR 6/2

Fig. 16a. Sample data for the "B" zone of the Cottonwood limestone member of the Beattie limestone.

Sample number	Location	Zone thick-ness	Sample weight (gram)	Residue						
				Coarse			Fine			
				Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
B-9-R	SW¼NE¼ sec. 21, T. 11 S., R. 7 E. Hillside outcrop	3.3	56.5	2.9	5.1	8.0	3.5	6.2	10.0	10 YR 6/2
B-10-R	SE¼NW¼ sec. 12, T. 11 S., R. 7 E. Hillside outcrop	2.5	56.6	0.3	5.3	1.0	2.9	5.1	8.0	5 YR 7/2
B-11-P	SE¼SW¼ sec. 27, T. 9 S., R. 8 E. Road cut	2.5	55.0	0.3	5.5	1.0	3.9	7.1	11.0	10 YR 6/2
B-12-G	NW¼NE¼ sec. 27, T. 11 S., R. 7 E. Hillside outcrop	2.4	55.3	3.7	6.7	11.0	3.4	6.1	9.0	5 YR 7/2
B-13-P	SE¼NE¼ sec. 34, T. 8 S., R. 7 E. Hillside outcrop	2.5	57.9	6.8	11.7	15.0	3.5	6.0	11.0	5 YR 6/1
B-14-R	SE¼NE¼ sec. 7, T. 11 S., R. 8 E. Road cut	2.5	57.3	7.1	12.4	15.0	3.2	5.6	9.0	5 Y 8/1
B-15-R	SE¼SE¼ sec. 8, T. 10 S., R. 7 E. Road cut	1.6	52.4	4.8	9.2	12.0	5.0	9.5	16.0	5 YR 7/2
Average	- - - - - - - - - - - - - - - -	2.7	54.6	3.4	6.7	9.2	3.5	6.5	9.7	- - - -

Fig. 16a (contd). Sample data for the "B" zone of the Cottonwood limestone member of the Beattie limestone.

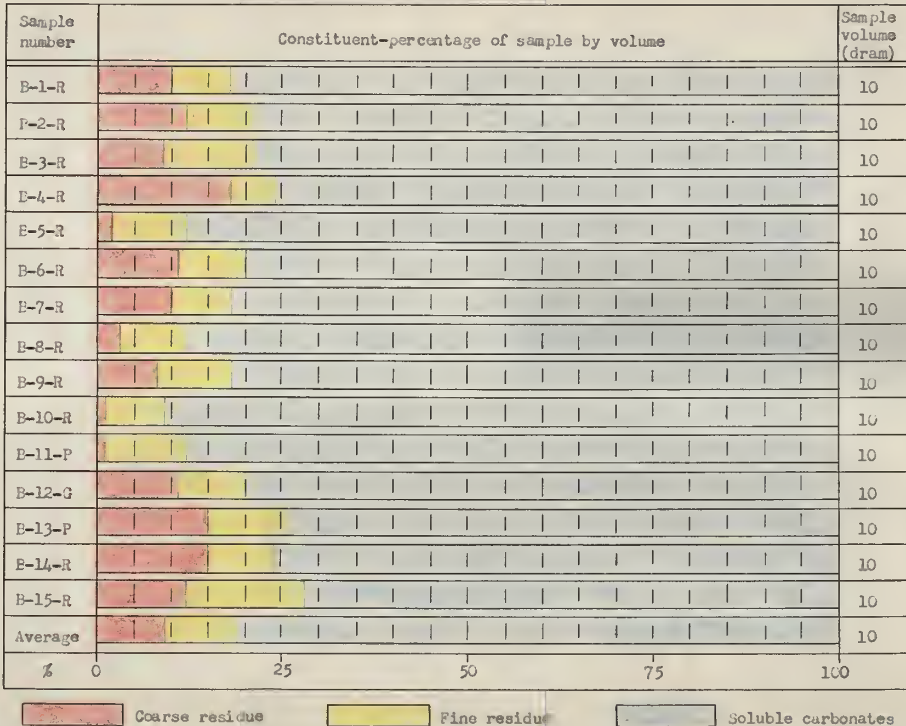

Fig. 16b. Constituent-percentage of sample by volume from the "B" zone of the Cottonwood limestone member of the Beattie limestone.

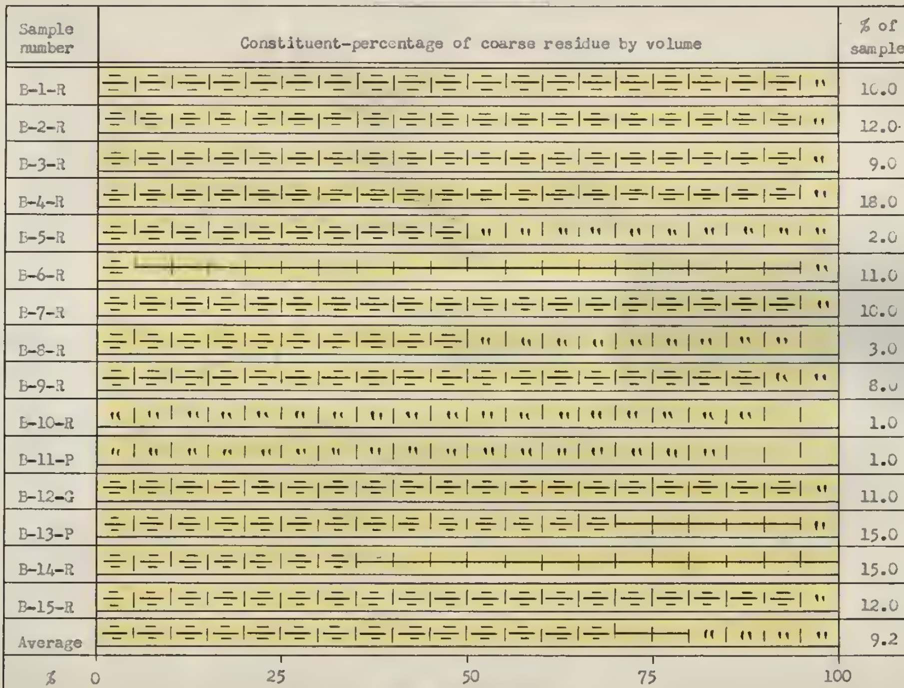

Fig. 16c. Constituent-percentage of coarse residue by volume from the "B" zone of the Cottonwood limestone member of the Beattie limestone.

pereietently very abundant in thie zone and echinoderm, brachiopod and molluecoidean remains are common also. The average thicknees of this zone ie approximately 2.7 feet, nearly 7 times that of the overlying A zone (Fig. 16a).

Register of Sampled Localities. Becauee samplee were taken at locations where the four zones were obtainable, the register of eampled localities for the "A" zone on pages 89 and 90 is the eame for the B zone; only the proper zone code letter need be subetituted to have the oorrect eample number.

Deecription of the Insoluble Residues. The fine residuss of this zone display a haphazard color pattern with grayish orange pink the predominating color in the western part of the area. Pale ysllowish brown is the common color toward the southeaet while varioue ehades of gray are ecattered throughout the area but are more prominent in the central and northern parts of the area. It is thought that strong currente at the time of deposition produced the confused color pattern but that ground water may also have been a contributing factor. The average zone B eample has 6.5 percent by weight and 9.7 percent by volume of fine reeidue (Fige. 16a and 16b).

White, opaque, chalky, spongy chert containing fusulinide is the most abundant coarse residue of this zone, but is lacking in samples B-10-R and B-11-R (Fig. 16c). Echinoderm beekite, with some brachiopod and molluecan fragments, was the only pereistent residue obeerved in this zone. The average sample is composed of approximately 20 percent by volume of this constituent. Smooth, gray, translucent, chalcedonic chert was etudied in samplee B-6-R, B-13-P and B-14-R without any obvioue aesociation as to location occurence. Traces of tubular eilica were observsd in eeveral eamples. The average sample of zone B contains 6.7 percent by wsight and 9.2 percent by volume of coaree residues (Figs. 16a and 16b).

Stratigraphic Correlation and Zone Identification by the Use of Insoluble Residues. The diagnostic coarse residues of the "B" zone are beekite and chalky, spongy, fossiliferous chert and the ratio of their occurence is 1:3 = beekite:chert. Reliable identification of this zone would have to be made upon the basis of the above discussion on samples taken from outcrops of this limestone.

Zone "C" of the Cottonwood Limestone Member. Lithology and Thickness of the "C" Zone. The "C" zone is a massive limestone layer overlying an argillaceous basal zone in the Cottonwood limestone member. Usually it forms the lower part of exposed Cottonwood outcrops in the Flint Hills area. Often it is separated from the overlying B zone by a thin parting of clay. This zone is light gray and usually weathers a yellowish tan gray. Zone C is similar to the overlying B zone in that it contains nodules of partly silicified material which weathers more slowly than the rest of the rock. This differential weathering imparts to the zone a flinty appearance; however, chalcedonic geodes or nodules rarely occur within this layer. The rough, pitted and porous weathered surface of this zone makes it easily distinguished from the overlying B zone or the underlying D zone, Plate 1, Fig. 2. Fusulinids (*Pseudofuslina emaciata*) are not as abundant within this zone as in the overlying A and B zones. Echinoderm, brachiopod and molluscan remains are common. The average thickness of this zone is approximately 1.3 feet (Fig. 17a).

Register of Sampled Localities. Because samples were taken at locations where the four zones were obtainable, the register of sampled localities for the A zone on pages 89 and 90 is the same as that for the C zone; only the proper zone code letter need be substituted to have the correct sample number (Fig. 17).

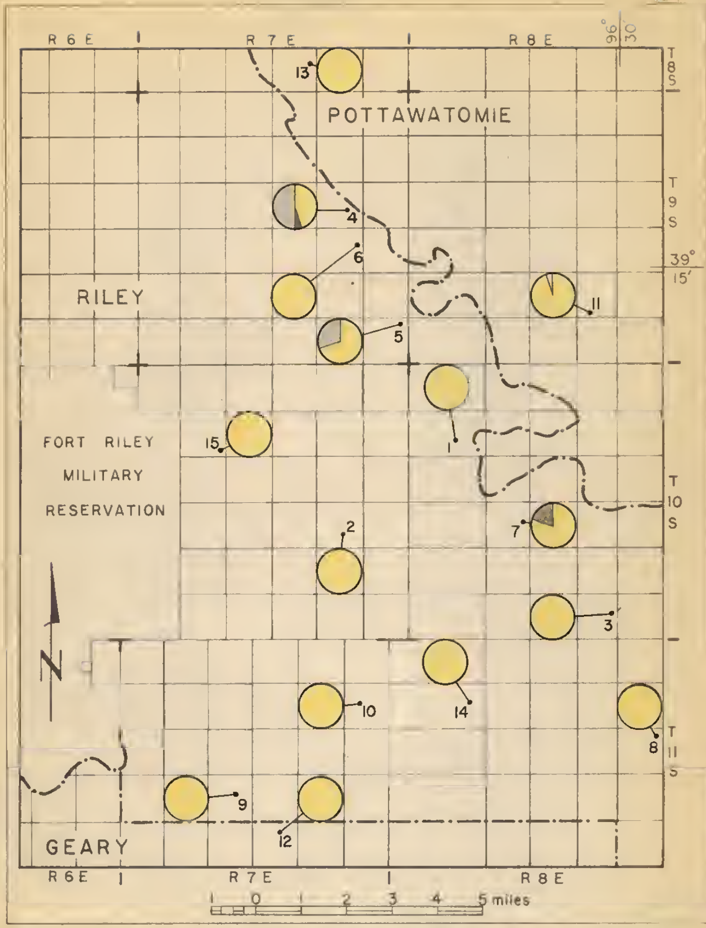

Fig. 17. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the "C" zone of the Cottonwood limestone member of the Beattie Limestone.

Sample number	Location	Zone thick-ness	Sample weight (gram)	Residue						
				Coarse			Fine			
				Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
C-1-R	NW¼SE¼ sec. 7, T. 10 S., R. 8 E. Hillside outcrop	0.8	53.4	2.5	4.7	7.0	5.0	9.4	14.0	10 YR 6/2
C-2-R	NW¼SE¼ sec. 23, T. 10 S., R. 7 E. Hillside outcrop	0.8	56.2	0.4	0.7	2.0	4.9	8.7	13.0	5 Y 6/1
C-3-R	SE¼NE¼ sec. 34, T. 10 S., R. 8 E. Road cut	0.8	57.1	0.2	0.3	1.0	4.2	7.3	11.0	10 YR 6/2
C-4-R	NW¼SE¼ sec. 14, T. 9 S., R. 7 E. Road cut	1.4	52.2	0.1	0.2	0.5	4.5	8.6	12.0	10 YR 6/2
C-5-R	NE¼NE¼ sec. 36, T. 9 S., R. 7 E. Hillside outcrop	0.9	53.4	0.1	0.2	1.0	4.8	9.0	13.0	5 Y 7/2
C-6-R	SE¼NE¼ sec. 23, T. 9 S., R. 7 E. Road cut	1.5	54.0	2.1	3.9	12.0	4.6	8.5	12.0	5 Y 7/2
C-7-R	SE¼NE¼ sec. 20, T. 10 S., R. 8 E. Quarry	1.5	54.9	0.5	0.9	2.0	4.4	8.0	12.0	5 Y 6/1
C-8-R	NE¼NE¼ sec. 14, T. 11 S., R. 8 E. Hillside outcrop	1.3	55.3	0.2	0.4	1.0	4.8	8.6	12.0	10 Y 6/2

Fig. 17a. Sample data for the "C" zone of the Cottonwood limestone member of the Beattie limestone.

Sample number	Location	Zone thickness	Sample weight (gram)	Residue						
				Coarse			Fine			
				Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
C-9-R	SW¼NE¼ sec. 21, T. 11 S., R. 7 E. Hillside outcrop	1.5	55.5	3.4	6.1	9.0	4.3	7.7	12.0	10 YR 6/2
C-10-R	SE¼NW¼ sec. 12, T. 11 S., R. 7 E. Hillside outcrop	1.5	53.8	0.7	1.3	3.0	4.1	7.6	11.0	10 YR 6/2
C-11-P	SE¼SW¼ sec. 27, T. 9 S., R. 8 E. Road cut	1.5	56.6	0.3	0.5	1.0	4.2	7.4	12.0	5 YR 7/2
C-12-G	NW¼NE¼ sec. 27, T. 11 S., R. 7 E. Hillside outcrop	1.2	55.7	0.4	0.7	1.0	4.4	7.9	11.0	10 YR 6/2
C-13-P	SE¼NE¼ sec. 34, T. 8 S., R. 7 E. Hillside outcrop	1.3	55.8	0.5	0.8	1.5	4.8	8.6	14.0	5 Y 8/1
C-14-R	SE¼NE¼ sec. 7, T. 11 S., R. 8 E. Road cut	1.5	53.8	4.1	7.6	11.0	3.3	6.0	9.0	5 Y 8/1
C-15-R	SE¼SE¼ sec. 8, T. 10 S., R. 7 E. Road cut	2.0	52.9	6.1	11.5	14.0	4.7	8.9	14.0	5 YR 7/2
Average	- - - - - - - - - - - - - - - - -	1.3	54.7	1.4	2.7	4.5	4.5	8.2	12.1	- - - -

Fig. 17a. (contd). Sample data for the "C" zone of the Cottonwood limestone member of the Beattie limestone.

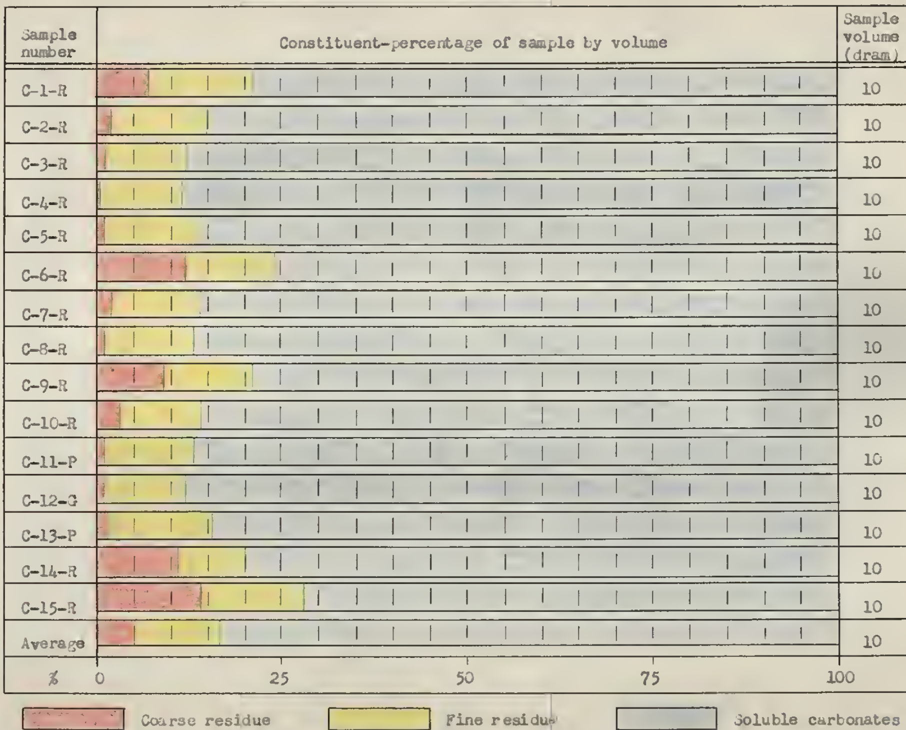

Fig. 17b. Constituent-percentage of sample by volume from the "C" zone of the Cottonwood limestone member of the Beattie limestone.

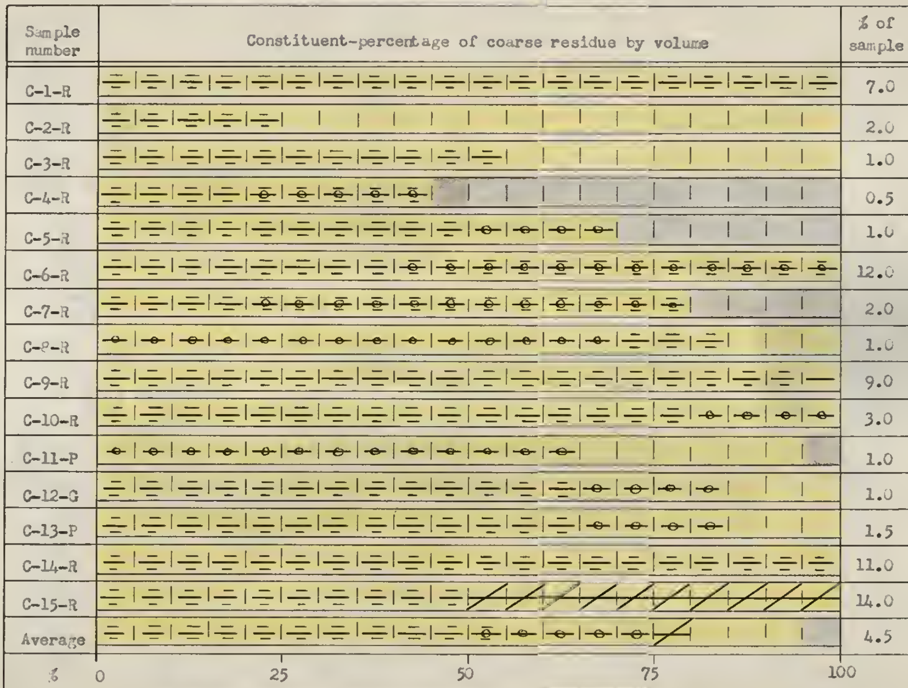

Fig. 17c. Constituent-percentage of coarse residue by volume from the "C" zone of the Cottonwood limestone member of the Beattie limestone.

Description of the Insoluble Residues. The color pattern produced by the fine residues in this zone is a random one with pale yellowish brown predominating in the southern part of the area. Throughout the remainder of the area various shades of yellow, gray, brown, and pink are indiscriminately distributed as if the clastic sediments had been promiscuously deposited by strong currents or during stormy periods. The percolation of ground water can not be entirely dismissed as an influencing factor in producing such a haphazard color arrangement. The average zone C sample has 8.2 percent by weight and 12.1 percent by volume of fine residue (Figs. 17a and 17b).

The average coarse residue sample of this zone is composed of approximately 75 percent by volume of white to pale cream, shalky, spongy to oolitic chert containing abundant fusulinids. This residue is not consistently the major constituent by volume of each sample, but it is always present in sufficiently large amounts, as may be seen in Fig. 17c. Silty appearing tubular silica was found in samples C-2-R, C-3-R, C-11-P, C-12-G and C-13-P, while traces of this residue were recorded in several other samples. Massive, fine, silty, micaceous clay was observed in C-4-R and C-5-R. Well consolidated silt apparently cemented with limonite was found in sample C-4-R. Smooth, fine to moderately fine, granulated, milky white to pink, chalcedonic chert is an important residue in sample C-15-R. This particular residue forms small geodes and is evident only at this location. The average sample of zone C contains 2.7 percent by weight and 4.5 percent by volume of coarse residues (Figs. 17a and 17b).

Stratigraphic Correlation and Zone Identification by the Use of Insoluble Residues. This zone is easily identified by its contained residues and by the lack of one material, beekite, which is found in the other three zones of the Cottonwood limestone member. Only uncontaminated samples taken from outcrope should be ueed for identification and correlation when working with thie zone or any zone of the same thicknees.

Zone "D" of the Cottonwood Limestone Member. Lithology and Thickneee of the "D" Zone. The basal argillaceous zone of the Cottonwood limestone member has been termed the "D" zone in thie report. Usually it is a maseive layer that locally ehowe gradation into the underlying Eskridge shale. Thie zone is often mantled by eoil but may be easily exposed by the use of a shovel. Nodulee of silicified material are present within thie zone but apparently weather at nearly the same rate as the matrix for the expoeed surfaces are not ae rough ae those displayed in the overlying B and C zones, Plate I, Fig. 2. Fusulinids are less abundant than in the three overlying zones. Echinoderm, brachiopod and molluscan remaine are common. The average thicknese of this zone is approximately 1.3 feet (Fig. 18a).

Regieter of Sampled Localitiee. Because samplee were taken at locations where the four zones were obtainable, the regieter of sampled localities from the A zone on pagee 89 and 90 ie the eame as that for the D zone; only the proper zone code lett r need be subetituted to have the correct sample number (Fig. 18).

Description of the Insoluble Reeidues. Within the area inveetigated, thie zone dieplaye a color pattern of fine residues at variance to that of the A zone. The trend of the gray sedimente is northeasterly with the majority of the brown claye and silts in the southeaetern part of the area. Thie lack of similarity of color patterns of this and the uppermost zone of the member euggeet an east to weet transgressive-regressive series during the deposition of the Cottonwood limeetone. The average zone D sample hae 9.6 percent by weight and 15.0 percent by volume of fine reeidues (Fige. 18a and 18b).

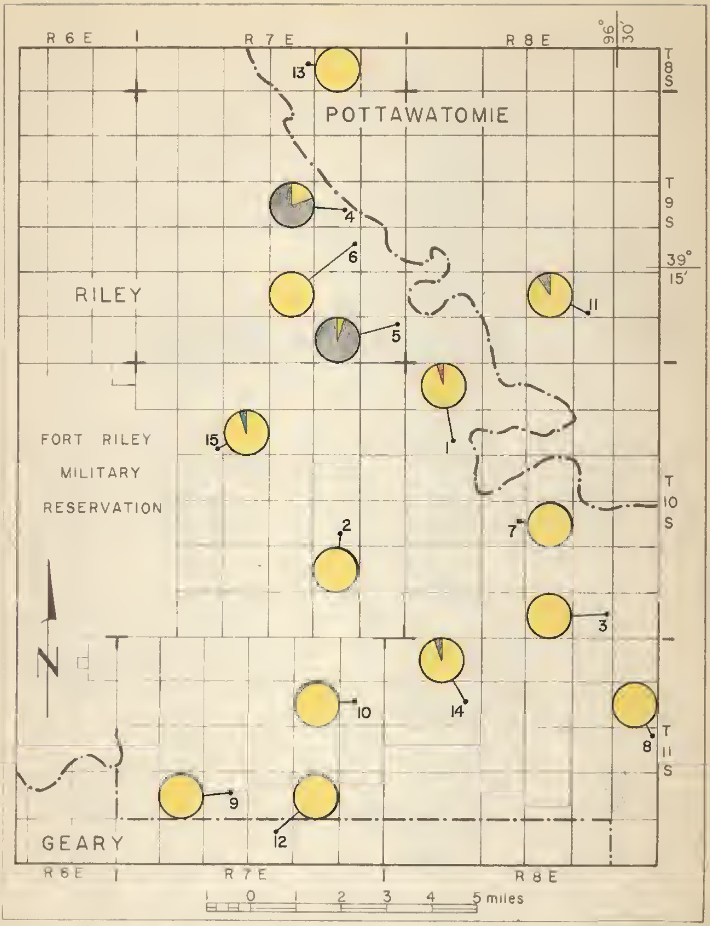

Fig. 18. Map of sampled sites with circlegrams showing the basic coarse residue constituents of the "D" zone of the Cottonwood limestone member of the Beattie limestone.

Sample number	Location	Zone thick-ness	Sample weight (gram)	Residue						
				Coarse			Fine			
				Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
D-1-R	NW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 7, T. 10 S., R. 8 E. Hillside outcrop	1.0	55.2	0.1	0.2	1.0	5.0	9.1	13.0	5 Y 4/1
D-2-R	NW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 23, T. 10 S., R. 7 E. Hillside outcrop	0.8	56.2	0.2	0.4	2.0	8.3	14.8	20.0	5 Y 8/1
D-3-R	SE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 34, T. 10 S., R. 8 E. Road cut	0.9	56.5	0.3	0.4	1.0	7.5	13.3	20.0	5 Y 8/1
D-4-R	NW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 14, T. 9 S., R. 7 E. Road cut	1.1	55.3	0.1	0.2	1.0	5.6	10.1	14.0	5 YR 6/4
D-5-R	NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 36, T. 9 S., R. 7 E. Hillside outcrop	2.0	53.5	0.3	0.6	2.0	4.9	9.2	14.0	5 Y 7/2
D-6-R	SE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 23, T. 9 S., R. 7 E. Road cut	1.8	56.9	0.2	0.4	4.0	5.3	9.3	13.0	5 Y 7/2
D-7-R	SE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 20, T. 10 S., R. 8 E. Quarry	1.3	57.0	0.6	1.1	1.0	4.3	7.5	11.0	10 YR 6/2
D-8-R	NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 14, T. 11 S., R. 8 E. Hillside outcrop	1.1	60.4	0.2	0.3	1.0	3.5	5.8	9.0	10 YR 6/2

Fig. 18a. Sample data for the "D" zone of the Cottonwood limestone member of the Beattie limestone.

Sample number	Location	Zone thickness	Sample weight (gram)	Residue						
				Coarse			Fine			
				Weight (gram)	% weight	% volume	Weight (gram)	% weight	% volume	Color number
D-9-R	SW¼NE¼ sec. 21, T. 11 S., R. 7 E. Hillside outcrop	1.6	58.8	0.3	0.5	2.0	7.6	13.1	20.0	5 Y 8/1
D-10-R	SE¼NW¼ sec. 12, T. 11 S., R. 7 E. Hillside outcrop	1.0	56.8	0.2	0.4	1.0	5.[illegible]	9.0	15.0	5 Y 8/1
D-11-P	SE¼SW¼ sec. 27, T. 9 S., R. 8 E. Road cut	1.2	58.5	0.4	0.7	2.0	4.4	7.9	15.0	5 YR 6/1
D-12-G	NW¼NE¼ sec. 27, T. 11 S., R. 7 E. Hillside outcrop	1.9	54.9	0.4	0.7	2.0	4.4	8.0	12.0	10 YR 6/2
D-13-P	SE¼NE¼ sec. 34, T. 8 S., R. 7 E. Hillside outcrop	1.4	57.2	0.3	0.5	1.0	4.5	7.9	14.0	5 Y 7/1
D-14-R	SE¼NE¼ sec. 7, T. 11 S., R. 8 E. Road cut	1.5	58.2	2.2	3.8	6.0	5.0	8.6	16.0	10 YR 6/2
D-15-R	SE¼SE¼ sec. 8, T. 10 S., R. 7 E. Road cut	1.2	54.5	0.2	0.4	1.0	5.5	10.1	17.5	5 YR 7/2
Average	- - - - - - - - - - - - - - - - -	1.3	56.7	0.4	0.7	2.0	5.4	9.6	15.0	- - - -

Fig. 18a (contd). Sample data for the "D" zone of the Cottonwood limestone member of the Beattie limestone.

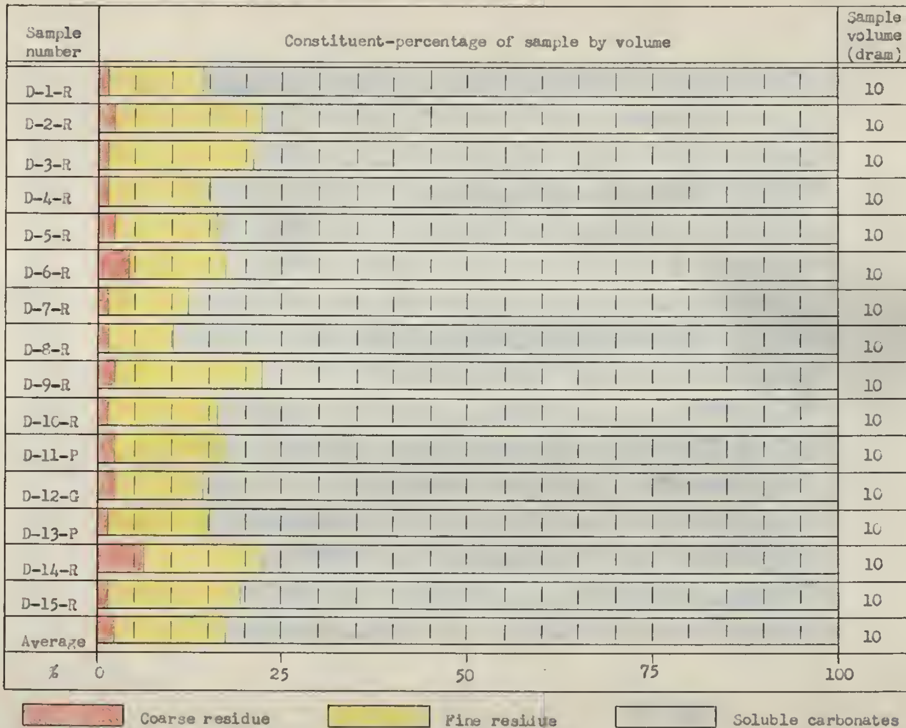

Fig. 18b. Constituent-percentage of sample by volume from the "D" zone of the Cottonwood limestone ter of the Beattie limestone.

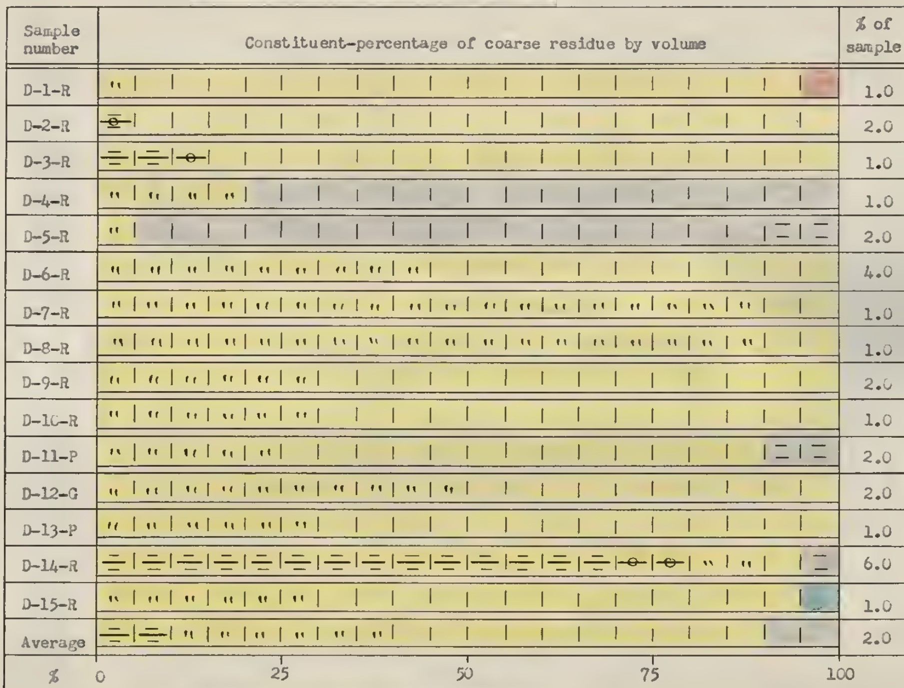

Fig. 18c. Constituent-percentage of coarse residue by volume from the "D" zone of the Cottonwood limestone member of the Beattie limestone.

Pale cream to light gray, silty appearing tubular silica is the major coarse residue constituent found in this zone. Although this siliceous residue did not appear in every sample studied, it does compose approximately 50 percent by volume of the average sample. Samples D-7-R and D-9-R are the only ones that do not display white to pale cream, oolitic to spongy beekite composed of siliceous brachiopod, molluscan and echinoderm fragments. Tan-gray, micaceous clay pellets in the shape of flat, thin, circular disks are the predominating residues in samples D-4-R and D-5-R, the only samples in which the siliceous "worm casts" are absent (Fig. 18). D-5-R and D-11-P each contain approximately 10 percent by volume of tan, spongy argillaceous material (Fig. 18c). White to pale cream, oolitic to spongy, chalky chert was recorded in samples D-6-R, D-7-R, and D-14-R as being their major constituents. Several traces of rounded, frosted, quartz grains and chalcedonic chert were scattered throughout the investigated area. Approximately 5 percent by volume of spongy limonite was observed in D-1-R and about the same percentage of glauconite appeared in D-15-R (Fig. 18c). The average sample of rock from zone D contains approximately 0.7 percent by weight and 2.0 percent by volume of coarse residues (Figs. 18a and 18b).

Stratigraphic Correlation and Zone Identification by the Use of Insoluble Residues. This zone could easily be distinguished from those overlying it on the basis of insoluble residues. Identification could be made on the basis of the following characteristics: fusulinids were not observed in the residues of this zone: "worm casts" were usually the predominant residue and where they were absent, there was found abundant argillaceous material in their lieu; a moderate percentage of oolitic to spongy beekite. Only outcrop sample should be used in attempting to correlate or identify this zone when using residue assemblages.

CONCLUSIONS

Sedimentation

Insoluble residues yield much information concerning silification, dolomitization, and facies changes on certain limestones and dolomites. They also serve as a rapid means of determining roughly the purity and suitability of limestones and dolomites for certain uses.

Because the area investigated has artificial and not geologic boundaries positive determination of the direction of clastic sedimentation and shoreline trends is not possible. From information that has been made available, however, it is believed that the source area for the fine residues in the Council Grove Group generally was east of their site of deposition.

Strata Identification and Correlation

It must be emphasized that it is only rarely that a particular residue alone from a restricted thickness of rock can be safely used for identification and correlation. The use of residue assemblages is similar to the use of fossil assemblages by paleontologists for correlation. Certain residue assemblages are valuable keys for identifying and correlating carbonate formations, member, and zones. It cannot be stressed too strongly that correlation of well cuttings by insoluble residues involves a thorough knowledge of the type of residues in a particular sequence of rocks in that area or depositional basin. Also, many residue correlations are dependent upon the sequence, as well as the assemblage. This is particularly true of the Council Grove Group of formations.

On page 119 is presented a table of correlation of the Council Grove group of limestones based entirely upon their contained insoluble residue assemblages. The stratigraphic sequence of the residue assemblages was ignored to obtain the presented ratings. In general, if the assemblage sequence is known, the over-all correlation of this group of rocks is very good.

Table 1. Identification and correlation of the Council Grove Group limestones based upon their contained insoluble residue assemblages.

Carbonate strata	Correlation rating
Funston Limestone	Very good
Crouse Limestone	Very good
Bader Limestone	
Middleburg limestone member	Good
Eiss limestone member	Good
Beattie Limestone	
Morrill limestone member	Doubtful
Cottonwood limestone member	Excellent
Zone A	Good
Zone B	Good
Zone C	Good
Zone D	Good
Grenola Limestone	
Neva limestone member	Fair
Burr limestone member	Fair
Red Eagle Limestone	
Howe limestone member	Doubtful
Glenrock limestone member	Doubtful
Foraker Limestone	
Long Creek limestone member	Fair
Americus limestone member	Good

<u>Ratios</u>. Presented in Figs. 19 and 20 are tables showing ratio of the mean percentage of weight of total residues to the percentage of volume of total residue of the various limestone strata investigated in this study. Because all other attempts to establish correlations between the percentages of weight to the percentages of volume proved unsuccessful, it was determined that these tables would best illustrate the "personality profile" of the

Council Grove group limestones.

General. Rapidly fluctuating shore limes and storm-generated currents disrupt the depositional pattern by creating local conditions that may easily be confused with those produced by the deposition of secondary minerals by ground water. It is the writer's opinion that the majority of the beekite and other similar residues described in this report are the result of silicification by the replacement method.

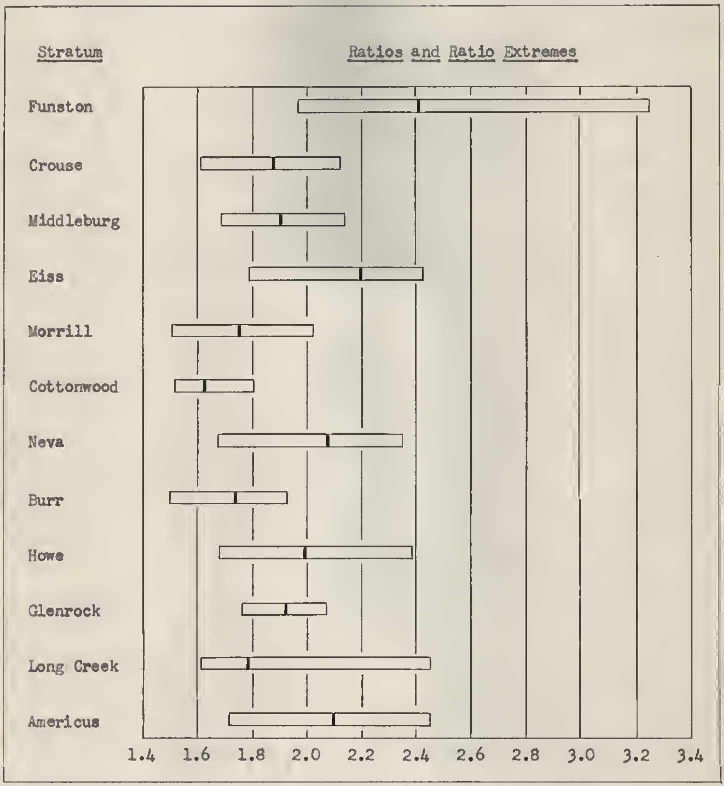

Fig. 19. Table of Council Grove Group limestones showing their mean percentage of weight of total residues to the percentage of volume of total residues ratios and their ratio extremes.

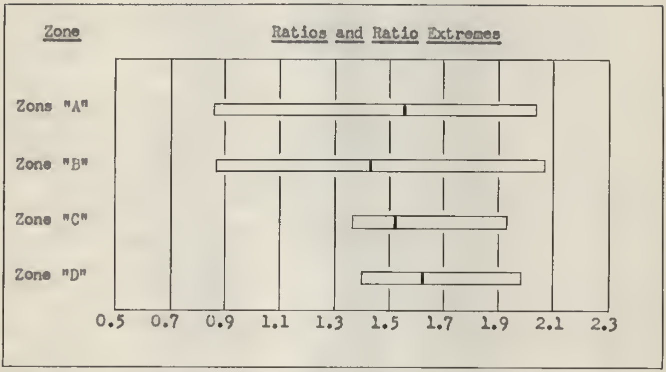

Fig. 20. Table of Cottonwood limestone member zones showing their mean percentage of wsight of total rssidues to the percentage of volume of total rssidues ratios and their ratio extremes.

ACKNOWLEDGMENTS

The writer desires to express appreciation and gratitude to Dr. Frank E. Byrne, Professor of Geology and Paleontology, who supervised the work throughout and contributed generously of his observations and many valuable suggestions during the course of the study; to Professor A. B. Sperry, Head of the Department of Geology and Geography, and Dr. J. R. Chelikowsky, Professor of Geology, for their helpful criticisms and suggestions; and to other members of the Department of Geology, Kansas State College, for their advice on certain field and laboratory problems.

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ABSTRACT

The insoluble residues of the limestones of the Council Grove Group are described and their occurrences illustrated, emphasis being given to these Permian rocks as they occur in the Manhattan, Kansas, area. The use of insoluble residues in the correlation and identification of carbonate strata is discussed. The manner of preparing, describing and recording of residues is also discussed in considerable detail. This report is descriptive and makes no attempt at regional geologic correlations due to the size of the investigated area but is of primary interest to subsurface stratigraphers, although it will servs the field geologist in checking field identifications. From information that has been made available, it is believed that the source area for the fine residues of the Council Grove Group generally was east of their site of deposition. It is strongly stressed that many residue correlations within this group of rocks are dependent upon the sequence, as well as the contained assemblages. The results of this investigation show that, if ths assemblage sequence is known, the overall correlation of these rocks is very good. The majority of the beekite and similar residuss described are thought to be the result of silicification by the replacement method. The collected and presented data displays very little relationship between the volumetric and weight measurements of the residues and samples from any limostone in this group.

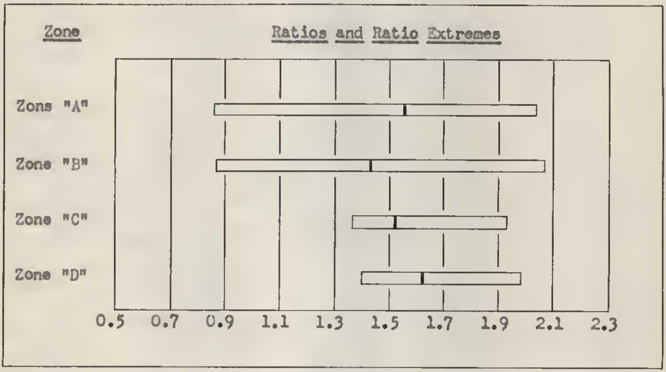

Fig. 20. Table of Cottonwood limestone member zones showing their mean percentage of weight of total residues to the percentage of volume of total residues ratios and their ratio extremes.

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The writer desires to express appreciation and gratitude to Dr. Frank E. Byrne, Professor of Geology and Paleontology, who supervised the work throughout and contributed generously of his observations and many valuable suggestions during the course of the study; to Professor A. B. Sperry, Head of the Department of Geology and Geography, and Dr. J. R. Chelikowsky, Professor of Geology, for their helpful criticisms and suggestions; and to other members of the Department of Geology, Kansas State College, for their advice on certain field and laboratory problems.

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ABSTRACT

The insoluble residues of the limestones of the Council Grove Group are described and their occurrences illustrated, emphasis being given to these Permian rocks as they occur in the Manhattan, Kansas, area. The use of insoluble residues in the correlation and identification of carbonate strata is discussed. The manner of preparing, describing and recording of residues is also discussed in considerable detail. This report is descriptive and makes no attempt at regional geologic correlations due to the size of the investigated area but is of primary interest to subsurface stratigraphers, although it will servs the field geologist in checking field identifications. From information that has been made available, it is believed that the source area for the fine residues of the Council Grove Group generally was east of their site of deposition. It is strongly stressed that many residue correlations within this group of rocks are dependent upon the sequence, as well as the contained assemblages. The results of this investigation show that, if ths assemblage sequence is known, the overall correlation of these rocks is very good. The majority of the beekite and similar residues described are thought to be the result of silicification by the replacement method. The collected and presented data displays very little relationship between the volumetric and weight measurements of the residues and samples from any limostone in this group.