CLAY MINERALOGY OF THE VILAS SHALE(UPPER PENNSYLVANIAN) IN WILSON AND MONTGOMERY COUNTIES

by

Carl B. Kinell III
B.S., The University of Kansas, 1962

Submitted to the Department of
Geology and the Faculty of the
Graduate School of The University
of Kansas in partial fulfillment
of the requirements for the degree of Master of Science.

Ada Swineford
Instructor in charge

William Merrill
For the department

May, 1964

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Figure

Plate

LIST OF TABLES

ABSTRACT

Samples of the Vilas Shale (Pennsylvanian) were taken across an area of a marine bank or reef build-up in southeastern Kansas. Studies of the clay mineralogy revealed the presence of illite, chlorite, and kaolinite. The chlorite was found to disappear with increasing elevation in the Vilas Shale.

Correlation of the clay minerals indicates a facies relationship between the Vilas Shale and the underlying Spring Hill Limestone. An increase in the relative intensity of the kaolinite peak with an increase in elevation within the section was noted at several localities.

Lateral variations in the clay mineralogy are inconclusive and no evidence of the direction of the source area could be determined.

The principal non-clay minerals in the area as determined by X-ray analysis are quartz, calcite, and feldspar.

INTRODUCTION

In Wilson and Montgomery counties, the Vilas Shale is a nonfossiliferous, gray to buff, predominately marine shale which ranges in thickness from less than 3 to more than 130 feet. The large variance in thickness is thought to be the result of a marine bank or reef buildup in the underlying Spring Hill Limestone. The buildup area (Fig. 1) is approximately 10 by 14 miles and consists of a thickening of the Spring Hill Limestone from 3 to 88 feet (Harbaugh, 1959).

The Vilas Shale is a formation in the Lansing Group which is in the Missourian Stage of the Pennsylvanian System. The Vilas Shale is overlain by the Captain Creek Limestone Member of the Stanton Limestone and is underlain by the Spring Hill Limestone Member of the Plattsburg Limestone.

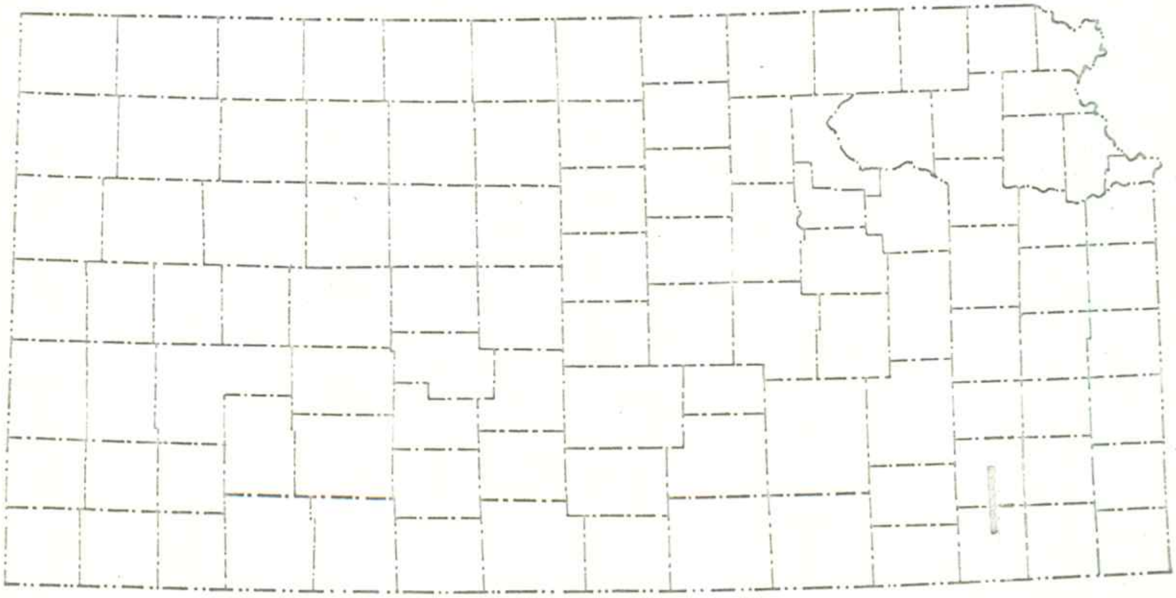

Figure 1. Location map of study area in Wilson and Montgomery counties.

Samples of the Vilas Shale from five sections extending across the buildup area were taken in order to determine the clay minerals present. An effort was made to collect a complete vertical section, where possible, and thus discover any vertical as well as any horizontal variations in the clay mineralogy. X-ray analyses were used to identify the clay minerals. In addition, the non-clay minerals that could be determined by X-ray analysis were reported.

Depending upon the variance in clay mineralogy and the assumption that clay mineral distribution is principally a function of source area rather than diagenesis, the Vilas Shale could be either a facies equivalent of the upper part of the Spring Hill Limestone or a later deposit.

Previous Work

Thickening of the Plattsburg Limestone in Wilson and Montgomery counties was first noted by Newell (1933). Chelikowsky and Burgat (1947) noticed the thinning of the Vilas Shale over the area where thickening was present in the underlying Spring Hill Limestone. To them, this indicated that perhaps the two formations were genetically related.

The Plattsburg and Vilas formations in the Fredonia quadrangle were described by Wagner and Harris (1953). Wilson (1957), in working on the overlying Stanton

Limestone in western Montgomery County, first interpreted the thickening of parts of that limestone to be the result of barrier reefs. Davis (1959) regarded the Spring Hill Limestone as a pre-Vilas barrier reef which formed a barrier to sediments from Oklahoma. An uplift in northern Oklahoma resulted in Vilas clastics filling the lagoon and overflowing the reef.

Harbaugh (1959) does not agree that the thickening of the Spring Hill Limestone represents a true reef and proposed the term "marine bank" to indicate a submerged shallow area rising above the sea floor. Wave resistance is not present to an appreciable degree as would be the case in a true reef. He agrees with Chelikowsky and Burgat that the Vilas Shale and Spring Hill Limestone represent facies equivalents.

Acknowledgments

I wish to express my appreciation to Dr. John Harbaugh for acquainting me with the various sections in Wilson and Montgomery counties and to Ted Jacques for his assistance in the collection of the samples.

The State Geological Survey provided financial support and transportation for the field work. Mr. Paul Franks ran several X-ray analyses on the Norelco diffractometer; he also aided in the interpretation of several patterns.

Dr. Ada Swineford, my advisory chairman, and Drs. H. A. Ireland, E. Gillerman, and D. F. Merriam

provided many helpful suggestions and reviewed the manuscript.

TECHNIQUES

Samples of the Vilas Shale were taken from five sections; four in Wilson County and one in Montgomery County (Fig. 2). Where possible, samples were collected every 2 feet vertically except at section C where samples one foot apart were taken. A pit dug 6 to 10 inches deep at each sample locality provided relatively unweathered material. Good outcrops of the Vilas Shale are present at each of the localities with the exception of section E in Montgomery County.

Shale interbedded with the Spring Hill Limestone at section C was collected. At this locality the Vilas Shale is only 3 feet thick and the Spring Hill attains its maximum vertical extent.

Samples selected for X-ray analysis were first examined with a binocular microscope to determine variations in color, lithology, and faunal assemblages. Identifiable minerals were recorded and hydrochloric acid was used to determine the presence of carbonate in the shale samples. Results of the optical examination are shown on Plate 1.

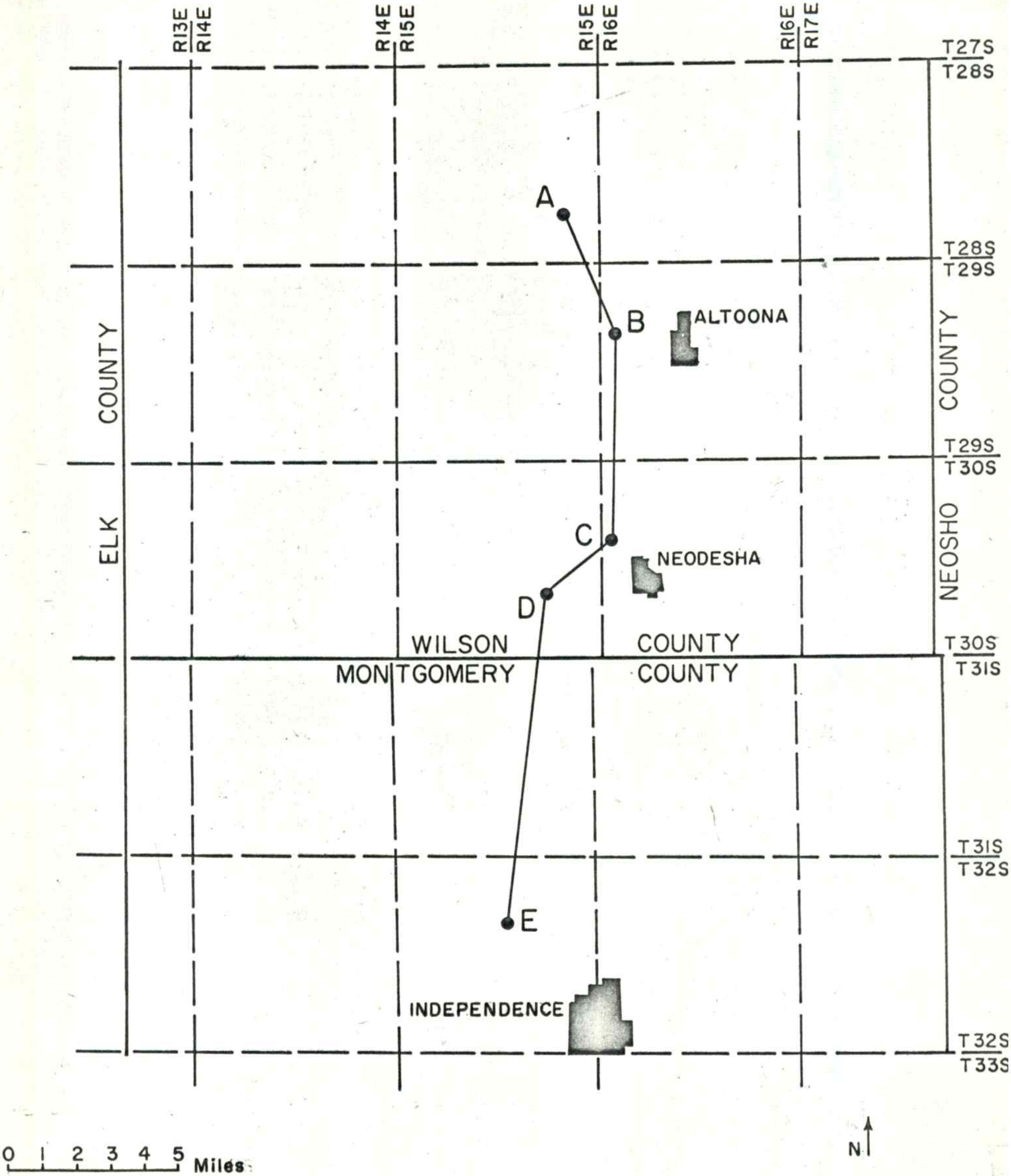

Figure 2. Location of sections studied in Wilson and Montgomery counties, Kansas.

Preparation for Identification of Non-Clay Minerals

After the optical examination, approximately 10 grams of the sample was ground to pass through a 61 micron screen. A small proportion of this material was used to form an unoriented sample which was later X-rayed. The rest of the material was used for preparation of oriented slides.

Preparation for Identification of Clay Minerals

The remainder of the ground sample was transferred to a 500 ml Ehrlenmeyer flask and distilled water was added. Flocculation of the clay was prevented by addition of a few drops of ammonium hydroxide. The flask was then shaken for at least 8 hours to allow the sample to disperse after which the sample was poured into a 600 ml beaker and enough distilled water added to fill the vessel. The suspension was allowed to stand for 4 hours and a medicine dropper was inserted to a depth of 5 cm to obtain particles less than 2 microns in size (Krumbein and Pettijohn, 1938, p. 97).

Four slides were filled with clay-water suspension and allowed to dry at room temperature. In this manner, the clay minerals settle to form an oriented sample with their basal planes parallel to the glass slide.

One of the slides was then sprayed with a mixture of glycerol and water in a one to two proportion. Another slide was heated to 450° in an electric oven and a third to 575°C for 30 minutes. Cooling with the door closed prevented peeling of the slides. X-ray diffractograms were made immediately after cooling to prevent an appreciable degree of rehydration.

A General Electric XRD-3 was used for the X-ray identifications except for nine samples run on a Norelco diffractometer. A total of 70 patterns were run using copper radiation with a nickel filter and a 1° beam slit. A 3° solar and a 2° receiving slit were used on the General Electric machine. The voltage was 45 kilovolts at 15 milliamps. A speed of 0.2° 2θ per minute was used from 2° to 60° 2θ.

The Norelco unit was equipped with a 1° beam slit and a .003 inch solar. Scanning rate was 1° 2θ per minute from 1° to 60°. Voltage was 35 kilovolts at 18 milliamps.

CLAY MINERAL IDENTIFICATION

Clay minerals were identified on the basis of data given in Brown (1961) and charts in Warshaw and Roy (1961). Warshaw and Roy present a very good introduction to procedures useful in the identification of clay minerals and include several tables giving step-by-step measures for analysis of various mixtures of clay minerals.

Sample D 0-2 is used as an illustration of the typical material found in the problem area. Illite, chlorite, and kaolinite are the clay minerals present in the sample. The sample was taken from the base of the Vilas Shale just above the Spring Hill Limestone about 2 miles south of the maximum thickening of the Spring Hill marine bank. Diffractometer patterns for this sample are given in Figure 3.

The 14.02 A° peak of the air-dried sample is indicative of either chlorite, vermiculite, or montmorillonite. Glycerol treatment did not cause an increase of the peak to 17 A° and this indicates the absence of an appreciable amount of montmorillonite. Heat treatment at either 450°C or 575°C failed to cause collapse of the peak as would be the case if vermiculite were present. Chlorite is the only clay mineral having a 14 A° peak that is not affected by glycerol or heat treatment.

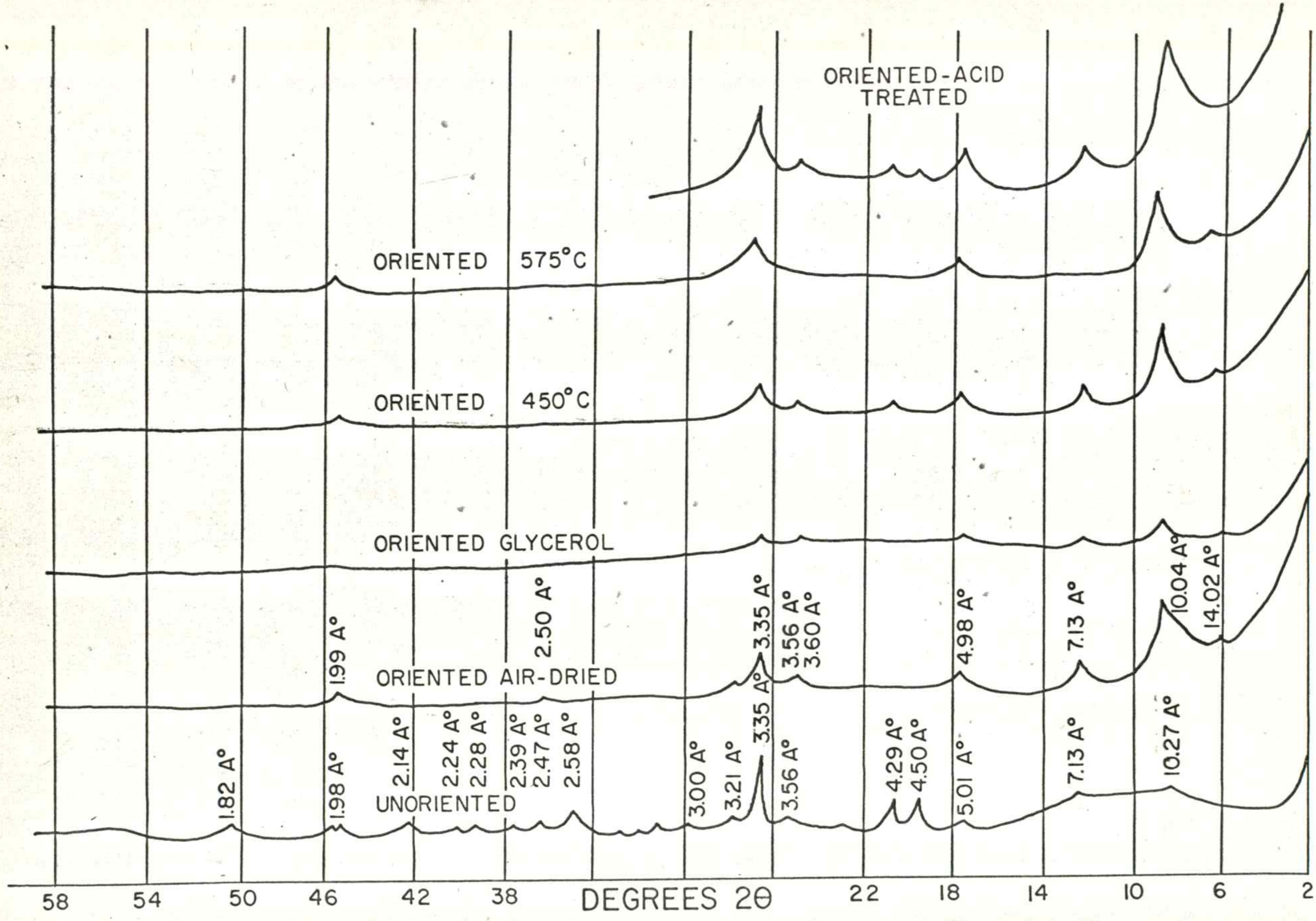

Figure 3. Diffraction patterns of D 0-2.

The 7.13 A^{o} and 3.56 A^{o} peaks are additional indications of chlorite(002 and 003).

The peaks at 10.04, 4.98, 3.35, and 1.99 A^{o} fit well the data given by Brown (1961) for basal reflections of illite. Powers (1957) has shown that asymmetry of the 001 illite peak towards the low-angle side with a corresponding broadening of the 002 peak and asymmetry of the 003 peak towards the high-angle side to be indicative of weathering. This feature shows quite well on the 10.04 A^{o}(or 001) peak of illite in this sample.

The broad peak in the vicinity of 3.56 - 3.60 A^{o} is somewhat indicative of kaolinite. Both chlorite and kaolinite in this area have a reflection and commonly the two closely spaced peaks merge to form a single broad peak. A part of the shale from this sample was boiled in 50 percent hydrochloric acid for 30 minutes to decompose any chlorite. An examination of the acid-treated sample reveals that the 14.02 A^{o} peak was eliminated while at least part of the 7.13 A^{o} peak remained. The retention of the 7.13 A^{o} peak with its elimination by heat treatment at 575°C is a good indication of kaolinite.

Calculation of the Relative Heights of Clay Mineral Peaks

The 001 basal reflections were used in the calculation of relative heights of clay mineral peaks. The relative height of a given clay mineral peak is determined by dividing the height by the combined heights of all 001 reflections of clay minerals in the pattern.

A difference in the reflecting powers of clay minerals exists and this must be taken into account. Murray (1954, p. 57) states:

> "...calculations showed that the reflecting power of the (001) plane of kaolinite has for all practical purposes three times the reflecting power of the (001) plane of illite and 2½ times the reflecting power of the chlorite (001) plane. Because of atomic substitutions in chlorite and illite, the reflecting powers of the (001) planes were considered as being one-third that of the (001) plane of kaolinite. The (002) plane of chlorite has a reflecting power of approximately one-half that of the (001) plane of kaolinite."

To correct for the difference in reflecting powers and the overlap of the 001 kaolinite peak by the 002 peak of chlorite, Murray (1954, p. 58) suggests:

> "Because the (001) plane of kaolinite has a reflecting power approximately 3 times that of the (001) planes of illite and chlorite,

> the values of the intensities of the illite and chlorite peaks were each multiplied by 3. The reflecting power of the (001) plane of kaolinite is approximately twice that of the (002) plane of chlorite; thus, one-third of the total intensity of the (001) kaolinite peak is due to the presence of the (002) reflection of chlorite because the (001) kaolinite reflection and the (002) chlorite reflection both appear at the same position."

Corrections for differences in reflecting power was followed, as suggested by Murray, except that the height of the 001 chlorite peak was multiplied by 2.5 rather than 3. The overlap of the 001 kaolinite peak by the 002 chlorite peak is somewhat compensated for by using the data above given by Murray; however, the results obtained are still inconsistent, as will be shown.

NON-CLAY MINERAL IDENTIFICATION

The diffraction pattern (Fig. 3) of sample D 0-2 may be used to illustrate the identification methods of the non-clay components. The presence of quartz is indicated by peaks near 4.27, 3.34, 2.46, 2.28, and 1.81 A°. The prominent peak at 3.34 A° is probably largely due to illite.

The peak at 3.21 A° along with the presence of another peak at 4.05 A° in other samples fits best the data given by Brown (1961) for feldspar. Calcite is indicated in other samples by a strong peak at 3.03 A°. Quartz and feldspar are the only non-clay minerals to appear of the diffraction pattern in Figure 3.

FACTORS CONTROLLING THE DISTRIBUTION OF CLAY MINERALS

A brief examination of the factors controlling clay mineral distributions should be made before an evaluation of the data obtained during this study can be attempted. Because application of X-ray diffraction techniques to clay and shale is comparatively recent, few firm conclusions have been reached as to the significance of clay mineral distribution patterns.

Importance of Source Area

The source area is the most important single factor influencing the distribution of clays in marine deposits according to the conclusions of clay mineralogists such as Weaver (1958a), Moberly (1963), and Keller (1956). Factors such as parent material, climate, pH, and salinity in the source area control the development of clay minerals. Weaver (1958a) believes parent material to be of special significance and presents examples of similiar composition between rocks of the land mass and clay minerals in the adjacent marine bodies.

Boswell (1952) has shown that the factor of climate is also of interest. Kaolinite group minerals form only under conditions of good drainage and a pH of 6.0 to 7.4. The formation of kaolinite has been shown to be prevalent where precipitation exceeds evaporation (Keller, 1956). Montmorillonite is prominent where evaporation is greater than precipitation. Keller believes the greater relative abundance of illite to be related to its being the first product of weathering when shale is exposed on the land.

Associated with the factor of climate is latitude. Correns (1939) has demonstrated kaolinite to be more prevalent in equatorial regions and attributes this to the weathering of lateritic soils in an acidic environment.

Glass (1958) believes kaolinite to be normally a detrital mineral with the exception of some authigenic material associated with sandstones. His work has shown that the nonmarine portion of some Pennsylvanian cyclothems is higher in kaolinite than the corresponding marine portion. Further work by Glass (1956) demonstrates, however, that difficulty is sometimes encountered in separating depositional environmental effects from those of the source area.

The area of the Mississippi River Delta has been studied by Taggart and Kaiser (1960). A change from predominantly montmorillonite to chlorite and illite is explained as a shift in source area from the Mississippi River drainage to that of the Black and Red rivers.

Most clay mineralogists agree that kaolinite is indicative of nonmarine and near shore environments of deposition (Grim, 1953). Illite and chlorite are regarded to be more the result of marine conditions and some evidence exists that chlorite is characteristic of continental slope deposits (Pinsak and Murray, 1958).

Importance of Diagenesis

Grim (1958) believes that there is considerable change in clay minerals as soon as the sediment enters the ocean, followed by more alteration afterwards which continues through a longer time. The adsorption of potassium by illite and chlorite is among the immediate changes. Montmorillonite could be expected to exchange cations such as calcium for potassium and magnesium. The three-layer minerals have a lower adsorptive capacity for ions and a greater period of time would be required for any change to take place (Grim, 1958). Cation availability must also be considered (Millot, 1949).

Work along the coast of California (Grim, Dietz, and Bradley, 1949) indicates that some chlorite is the result of diagenesis. A change from kaolinite to illite in a marine environment was also suggested. Johns and Grim (1958) have interpreted the change from montmorillonite in Mississippi River sediments to chlorite and illite in the Gulf of Mexico as evidence of diagensis.

Weaver (1958a), in a compilation of the work done on diagenesis, shows that nearly all major clay minerals have been supposedly demonstrated to change to all other major clay minerals. He offers this as evidence of the questionability of the role of diagenesis. Most of the evidence for diagenesis is very inadequate and is based on the relative increase or decrease of one mineral compared to another. Weaver suggests that the only way to synthesize data regarding clay mineral distributions is to accept the hypothesis that source area is of prime importance until it can be demonstrated that diagenesis actually takes place. It is on this basis that the conclusions in this study were made.

DISCUSSIONS OF RESULTS

Variations in Clay Minerals

Table 1 lists the relative peak heights of clay mineral 001 reflections present in the various sections. It should be noted that figures given for any one sample are relative to the heights of other clay mineral peaks present in that sample only and are not an absolute percentage of clay minerals. The heights of the peaks were measured directly although the intensity scale in the General Electric XRD-3 diffractometer is logarithmic; hence a very high peak would be indicative of a greater amount of clay than is indicated by the figures.

The relative heights for illite peaks remain within a range of approximately 70 to 90. Kaolinite peak heights range from a relative height of 6 to 25 and chlorite peak heights from 0 to 15.

Vertical Variation

The most prominent vertical change in the clay mineralogy of most sections is an absence of chlorite near the top of each shale section. With the exception of section C, chlorite is present in the lower parts of the sections. It is found in the shale interbedded with the Spring Hill Limestone at section C. At section D, chlorite is found in shale assigned to the Captain Creek Limestone above the Vilas Shale. Only trace amounts of chlorite were noted in the shale in the

Table 1. Relative Heights of 001 Clay Mineral Peaks

Section A. Road cut 6 miles northwest of Altoona. NW NW sec. 26, T. 28 S., R. 15 E.

Sample Number	Kaolinite	Chlorite	Illite
*130 - 131	20.3	0.00	79.7
118 - 120	16.2	0.00	83.8
*110 - 112	9.60	0.00	90.4
100 - 102	11.8	0.00	88.2
*92 - 94	8.70	0.00	91.3
80 - 82	13.7	trace	86.3
*70 - 72	6.20	5.28	88.5
61 - 62	20.4	trace	79.6
50 - 52	9.25	15.1	75.6
40 - 42	16.3	trace	83.7
30 - 32	25.7	0.00	74.3
10 - 12	9.70	10.0	80.3
0 - 2	14.5	9.10	76.4

Section B. Road cut along Kansas Highway 47, 2 miles west of Altoona. NW sec. 18, T. 29 S., R. 16 E.

Sample Number	Kaolinite	Chlorite	Illite
18 - 20	12.5	0.00	87.5
14 - 16	10.6	trace	89.4
10 - 12	16.6	11.9	71.5
5 - 6	10.5	10.9	78.6
0 - 2	7.65	13.2	79.1

* Samples run on Norelco diffractometer. All others were run on the General Electric X-ray diffractometer.

Table 1. (continued)

Section C. Carr limestone quarry 1 mile northwest of Neodesha. NW sec. 18, T. 30 S., R. 16 E.

Sample Number	Kaolinite	Chlorite	Illite
2 - 3	9.60	0.00	90.4
1 - 2	10.0	trace ?	90.0
*0 - 1	10.7	0.00	89.3
Shale in Spring Hill	7.70	11.3	81.0

Section D. Road cut along Kansas Highway 96, 2.5 miles west of Neodesha. SE SW sec. 23, T. 30 S., R. 15 E.

Sample Number	Kaolinite	Chlorite	Illite
*C.C. 3	11.2	5.85	83.0
C.C. 2	11.4	15.3	73.3
12 - 14	12.4	trace ?	87.6
8 - 10	10.2	11.8	78.0
4 - 6	11.7	11.9	76.4
0 - 2	7.05	11.3	81.6
S.H. 1.5 - 2.5	20.1	trace ?	79.9
S.H. 0 - 1.5	13.9	trace ?	86.1

Section E. Stream bank 4 miles northwest of Independence. SE sec. 9, T. 32 S., R. 15 E.

Sample Number	Kaolinite	Chlorite	Illite
*70	17.0	trace ?	83.0
60	8.70	trace	91.3
*50	6.57	5.63	87.8

Spring Hill at this locality. Diffraction patterns of the variations found in Vilas Shale samples from section D are given in Figure 4.

The absence of chlorite in the Vilas Shale at section C and its presence in the shale stringers of the underlying Spring Hill may be indicative of a facies relationship between the two units. If the Vilas Shale represented only a compressed section, chlorite should be present in the shale overlying the Spring Hill Limestone. However, before the evidence of such a facies relationship can be fully accepted, an evaluation of both the effect of weathering and diagenesis must be made.

Samples from the Captain Creek of section D contain an appreciable amount of chlorite while material from the top of the Vilas Shale in an underlying part of the section contains no chlorite. This would seem to indicate weathering alone is not the cause of the upward disappearance of chlorite, for if weathering was the only cause of the disappearance, chlorite should be removed from the samples in the Captain Creek.

The relative height of the kaolinite peaks does not show any consistent change vertically in section A. As stated previously, the overlapping of the kaolinite and chlorite peaks causes difficulties in obtaining results. An examination of the figures for kaolinite

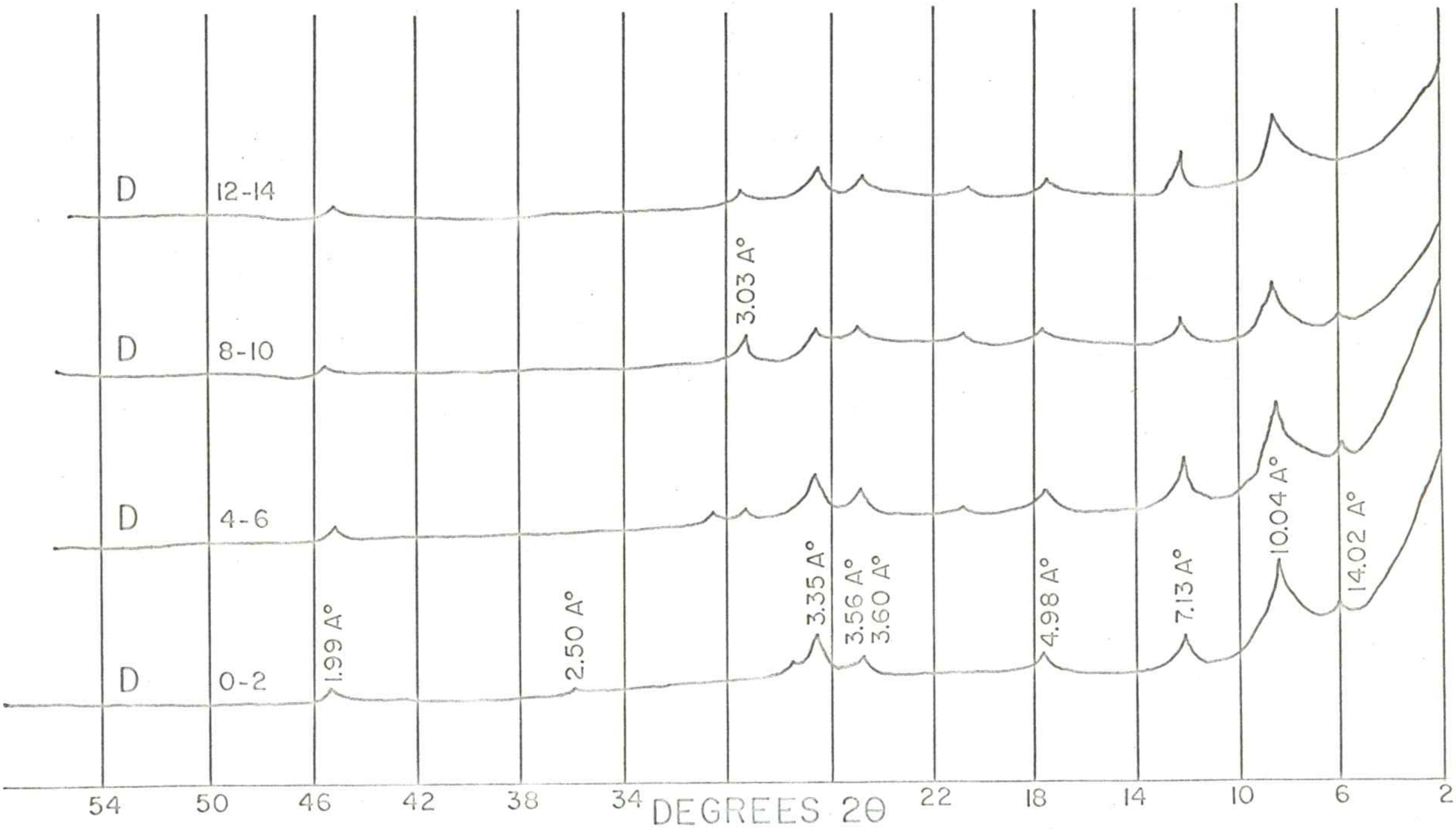

Figure 4. Oriented, air-dried diffraction patterns from section D. Notice that the 14 A° peak of chlorite disappears with increasing elevation.

above the point where chlorite drops out, shows a tendency for the relative amount of kaolinite to increase with increasing height within the section. Section C does not show this increase, possibly owing to the closeness of the samples. An increasing amount of kaolinite may be indicative of conditions becoming more nonmarine in nature. This would support the idea of Davis (1959) for an uplift in northern Oklahoma with subsequent burial of the reef by clastics of Vilas lithology.

That all of the Vilas Shale is not post-Spring Hill may also be supported by the presence of chlorite in sections on both sides of the marine bank. The marine bank could be assumed to have been somewhat of a barrier to detrital sediments from the south. If the chlorite was deposited first and the sediments later graded into a non-chloritic clay, the sediments to the north of the marine banks should be dominantly non-chloritic because chlorite is not present in the sediments of section C. A source area to the south as suggested by Moore (1936) is required for this evaluation.

Horizontal Variations

An examination of the figures for kaolinite (Table 1) in sections taken from the north compared with sections further south shows no distinct change in the relative heights of the kaolinite peaks. The source area as indicated by an increase in kaolinite is inconclusive in this area.

A study of a greater horizontal extent of the Vilas Shale is perhaps necessary to detect significant changes in the kaolinite. Values for chlorite and illite also yield no consistent changes in a lateral direction. A source area to the east would also tend to provide fairly constant values in the clay mineralogy of a north-south section.

Variations in Non-Clay Minerals

Figures given in Table 2 for all minerals were calculated in a manner similiar to those for the clay minerals. The 4.29 A^{O} peak of quartz, 3.21 A^{O} peak of feldspar, and 3.03 A^{O} peak of calcite were used. The total peak height of all 001 basal reflections were taken to calculate the clay mineral component. No reference was found on the reflecting powers of the non-clay minerals with respect to the clay minerals or each other. A one-to-one relationship was assumed.

Considerable variation in the relative peak heights for the various non-clay minerals can be noted in Table 2. Some tendency towards the occurence of fewer clay minerals with increasing height in the section can be noted in sections C and D, possibly reflecting an influx of coarser sediments. Section B, however, seems to contradict this hypothesis. The figures for relative peak heights of calcite can be seen to vary considerably and the calcite, to a large degree, may be secondary.

Table 2. Relative Heights of All Mineral Peaks Based on Unoriented Samples

Section A. Road cut 6 miles northwest of Altoona. NW NW sec. 26, T. 28 S., R. 15 E.

Sample Number	Clay	Quartz	Calcite	Feldspar
130 - 131	16.3	23.2	53.5	7.00
118 - 120	35.9	41.0	12.8	10.3
100 - 102	36.7	40.0	10.0	13.3
80 - 82	33.3	55.6	0.00	11.1
50 - 52	33.3	43.0	7.30	16.4
30 - 32	42.1	47.4	0.00	10.5
0 - 2	40.0	32.5	12.5	15.0

Section B. Road cut along Kansas Highway 47, 2 miles west of Altoona. NW sec. 18, T. 29 S., R. 16 E.

Sample Number	Clay	Quartz	Calcite	Feldspar
18 - 20	53.0	35.0	0.00	12.0
14 - 16	46.1	38.4	0.00	15.5
10 - 12	39.0	36.6	14.6	9.75
5 - 6	35.7	39.3	10.7	14.3
0 - 2	28.1	25.0	40.7	6.25

Section C. Carr limestone quarry 1 mile northwest of Neodesha. NW sec. 18, T. 30 S., R. 16 E.

Sample Number	Clay	Quartz	Calcite	Feldspar
1 - 2	8.30	16.7	75.0	0.00
0 - 1	24.3	17.7	54.9	3.03
Shale in Spring Hill	10.1	20.3	56.5	13.1

Table 2. (continued)

Section D. Road cut along Kansas Highway 96, 2.5 miles west of Neodesha. SE SW sec. 23, T. 30 S., R. 15 E.

Sample Number	Clay	Quartz	Calcite	Feldspar
12 - 14	18.0	23.4	50.5	8.10
8 - 10	13.6	13.6	68.5	4.56
0 - 2	31.0	48.2	0.00	20.8
S.H. 0 - 1.5	36.4	39.4	0.00	24.2

Section E. Stream bank 4 miles northwest of Independence. SE sec. 9, T. 32 S., R. 15 E.

Sample Number	Clay	Quartz	Calcite	Feldspar
60	23.6	36.7	18.7	21.0

Visible veinlets of calcite cutting the bedding of the shale were noted in several shale samples.

The presence of secondary calcite tends to obscure, for the most part, interpretations of changes in the primary detrital minerals. An examination of the figures provides few consistent patterns in changes of the the non-clay components.

In order to secure information on the detrital minerals alone, a recalculation of the data given in Table 2 was made. Calcite was omitted and the relative peak heights of quartz, feldspar, and the clay mineral content was determined. Recalculation resulted in the figures given in Table 3.

Data for the feldspar indicate a greater relative abundance of this mineral in sections to the south of the buildup area. This may reflect the existence of a source area to the south; however, the increase in feldspar content is not great.

Sections A and B, north of the marine bank, show a reduction in relative peak heights for the total clay mineral content beginning at the bottom of the sections and traveling upwards. After a low point is reached, the relative clay mineral content begins to increase. It is thought that this may be an indication of the marine bank presenting a greater and greater obstacle to the passage of detrital sediments from the south. Marine bank development subsided with a greater influx of detrital material from the source area.

Table 3. Relative Heights of Mineral Peaks Excluding Calcite

Section A. Road cut 6 miles northwest of Altoona. NW NW sec. 26, T. 28 S., R. 15 E.

Sample Number	Clay	Quartz	Feldspar
130 - 131	34.7	50.2	15.1
118 - 120	41.2	47.1	11.7
100 - 102	40.8	44.5	14.7
80 - 82	33.3	55.6	11.1
50 - 52	35.9	46.4	17.7
30 - 32	42.1	47.4	10.5
0 - 2	45.7	37.1	17.2

Section B. Road cut along Kansas Highway 47, 2 miles west of Altoona. NW sec. 18, T. 29 S., R. 16 E.

Sample Number	Clay	Quartz	Feldspar
18 - 20	53.0	35.0	12.0
14 - 16	46.1	38.4	15.5
10 - 12	45.6	42.9	11.5
5 - 6	40.0	44.0	16.0
0 - 2	47.2	42.1	10.7

Section C. Carr limestone quarry 1 mile northwest of Neodesha. NW sec. 18, T. 30 S., R. 16 E.

Sample Number	Clay	Quartz	Feldspar
1 - 2	33.2	66.8	0.00
0 - 1	54.0	39.3	6.70
Shale in Spring Hill	23.2	46.7	30.1

Table 3 (continued)

Section D. Road cut along Kansas Highway 96, 2.5 miles west of Neodesha. SE SW sec. 23, T. 30 S., R. 15 E.

Sample Number	Clay	Quartz	Feldspar
12 - 14	36.3	47.3	16.4
8 - 10	42.9	42.9	14.2
0 - 2	31.0	48.2	20.8
S.H. 0 - 1.5	36.4	39.4	24.2

Section E. Stream bank 4 miles northwest of Independence. SE sec. 9, T. 32 S., R. 15 E.

Sample Number	Clay	Quartz	Feldspar
60	29.0	45.1	25.9

Relative heights of quartz peaks show little consistent change and remain fairly constant, with the exception of a high figure for the uppermost sample from section C. This may indicate the influx of a greater amount of detrital material as the Vilas clastics overflowed the marine bank.

SUMMARY AND CONCLUSIONS

The clay mineralogy of the Vilas Shale taken above the area of maximum marine bank development in the Spring Hill Limestone and the samples taken in the shale stringers within the limestone when compared with sections on either side of the bank may indicate a facies relationship. A complete section of the Vilas Shale overlying the Spring Hill is apparently not present as indicated by the absence of chlorite.

A consistent decrease in the relative chlorite content with increasing elevation is noted in sections taken on both sides of the marine bank. An increase in the relative heights of the kaolinite peaks is discernible where chlorite is not present. The clay minerals present in the area are comprised chiefly of illite with varying amounts of chlorite and kaolinite.

Direction of source area is not discernible from an examination of the clay fraction, perhaps owing to an insufficient lateral extent of the sections studied or to a source area more to the east.

Weathering does not seem to be an important factor in destruction of chlorite as shown by the presence of chlorite in samples from the Captain Creek overlying the Vilas Shale at section C. The effect of diagenetic changes, if such occurred, was not discernible.

SUGGESTIONS FOR FURTHER STUDY

Assuming a source area to the south, comparisons of samples of the Vilas Shale from southeastern Kansas with sections taken farther north and south might provide more knowledge of the source area through a more significant lateral variation in the clay mineralogy. Size analysis of the non-clay detrital material could provide additional evidence of source area.

Samples of the Vilas Shale taken from drill hole cuttings in the same area could be compared with surface material to determine more precisely the role of recent weathering in the control of the clay mineral content.

BIBLIOGRAPHY

Boswell, P.G.H. (1952) The contribution of clay mineralogy to the study of the diagenesis of sediments: Clay Minerals Bull., v. 1, p. 246-251.

Brown, G. (1961) The x-ray identification and crystal structures of clay minerals: Mineralogical Society, London, 544 p.

Carroll, D., and Starkey, H.C. (1958) Effect of sea-water on clay minerals: Clays and Clay Minerals-Proceedings of the Seventh National Conference, p. 167-177.

Chelikowsky, J.R., and Burgat, V. (1947) Structures and convergence of the formations in the Lansing group, Wilson County, Kansas: Kansas Acad. Sci. Trans., v. 50, p. 89-96.

Correns, C.W. (1939) Pelagic sediments of the North American Ocean: Recent marine sediments-a symposium, Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 4, p. 373-395.

Davis, J.C. (1959) Reef structure in the Plattsburg and Vilas Formations (Missourian) in southeast Kansas: Compass (Sigma Gamma Epsilon), v. 36, p. 319-335.

Glass, H.D. (1958) Clay mineralogy of Pennsylvanian sediments in southern Illinois: Clays and Clay Minerals, Nat. Acad. Sci. - Nat. Res. Council, pub. 566, p. 227-241.

__________, Potter, P.E., and Siever, R. (1956) Clay mineralogy of some basal Pennsylvanian sandstones, clays, and shales: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 750-754.

Grim, R.E. (1953) Clay Mineralogy: McGraw-Hill, New York, 384 p.

__________ (1958) Concept of diagenesis in argillaceous sediments: Am. Assoc. Petroleum Geologists Bull., v. 42, p. 246-253.

__________, Dietz, R.S., and Bradley, W.F. (1949) Clay mineral composition of some sediments from the Pacific Ocean off the California Coast and the Gulf of California: Geol. Soc. America Bull., v. 60, p. 1785-1808.

Harbaugh, J.W. (1959) Marine bank development in Plattsburg limestone (Pennsylvanian), Neodesha-Fredonia area, Kansas: Kansas Geol. Survey Bull. 134, Part 8, p. 291-331.

____________ (1962) Pennsylvanian marine banks in southeastern Kansas: Kansas Geol. Society Guidebook.

Johns, W.D., and Grim, R.E. (1958) Clay mineral composition of recent sediments from the Mississippi River Delta: Jour. Sed. Petrology, v. 28, p. 186-199.

Keller, W.D. (1956) Clay minerals as influenced by environments of their formation: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 2689-2710.

Krumbein, W.C., and Pettijohn, F.J. (1938) Manual of sedimentary petrography: Appleton-Century-Crofts, New York, 549 p.

Millot, G. (1949) Relations entre la constitution et la genèse des roches sédimentaires argileuses: Géol. Appliq. et Prosp. Min., v. 2, L'Univ. Nancy, 352 p.

Milne, I.H., and Earley, J.W. (1958) Effects of source and environment on clay minerals: Am. Assoc. Petroleum Geologists Bull., v. 42, no. 2, p. 328-338.

Moberly, R. Jr. (1963) Amorphous marine muds from tropically weathered basalt: Amer. Jour. Sci., v. 261, p. 767-772.

Moore, R.C. (1936) Stratigraphic classification of the Pennsylvanian rocks of Kansas: Kansas Geol. Survey Bull. 22, 256 p.

Murray, H.H. (1954) Genesis of clay minerals in some Pennsylvanian shales of Indiana and Illinois: Clays and Clay Minerals-Proceedings of the Second National Conference, p. 47-67.

____________, and Harrison, J.L. (1956) Clay mineral composition of recent sediments from Sigsbee Deep: Jour. Sed. Petrology, v. 26, p. 363-368.

Newell, N.D. (1933) The stratigraphy and paleontology of the upper part of the Missouri Series in eastern Kansas: Unpublished Ph. D. dissertation, Yale University.

Pinsak, A.P., and Murray, H.H. (1958) Regional clay mineral patterns in the Gulf of Mexico: Clays and Clay Minerals-Proceedings of the Seventh National Conference, p. 167-177.

Powers, M.C. (1957) Adjustment of land derived clays to a marine environment: Jour. Sed. Petrology, v. 27, p. 355-372.

Scafe, D. (1963) A comprehensive study of six sections of the Deer Creek Limestone in Nebraska, Missouri, and Kansas: Unpublished Masters thesis, Univ. of Kansas.

Taggart, M.S., and Kaiser, A.D. (1960) Clay mineralogy of Mississippi River deltaic sediments: Geol. Soc. America Bull., v. 71, p. 521-530.

Wagner, H.C., and Harris, L.D. (1953) Stratigraphy of outcropping Pennsylvanian rocks of the Fredonia quadrangle, Kansas: U.S. Geol. Survey Oil and Gas Invest. Chart 48.

Warshaw, C.M., and Roy, R. (1961) Classification and a scheme for the identification of layer silicates: Geol. Soc. America Bull., v. 72, p. 1455-1492.

Weaver, C.E. (1957) The clay petrology of sediments: Clays and Clay Minerals-Proceedings of the Sixth National Conference, p. 155-183.

____________ (1958a) Origin and significance of clay minerals in sedimentary rocks: Am. Assoc. Petroleum Geologists Bull., v. 42, p. 245-271.

____________ (1958b) Clay petrology of Upper Mississippian-Lower Pennsylvanian sediments of central United States: Am. Assoc. Petroleum Geologists Bull., v. 42, p. 272-309.

____________ (1960) Possible uses of clay minerals in the search for oil: Clays and Clay Minerals-Proceedings of the Eighth National Conference, p. 214-227.

Wilson, F.W. (1957) Barrier reefs of the Stanton formation (Missourian) in southeast Kansas: Kansas Acad. Sci. Trans., v. 60, p. 429-436.

PLATE I

STRATIGRAPHIC SECTIONS OF VILAS SHALE

by

Carl B. Kinell III