ANALYSIS OF MISSISSINEWAY SHALE-LISTON CREEK LIMESTONE CONTACT IN NORTHEASTERN INDIANA

A THESIS

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by

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TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>A. Purpose of Study</td>
<td>1</td>
</tr>
<tr>
<td>B. Significance</td>
<td>8</td>
</tr>
<tr>
<td>C. Selection of Field Localities</td>
<td>8</td>
</tr>
<tr>
<td>II. GEOLOGIC SETTING</td>
<td></td>
</tr>
<tr>
<td>A. Structural Setting</td>
<td>12</td>
</tr>
<tr>
<td>B. Stratigraphy of Wabash Formation</td>
<td>15</td>
</tr>
<tr>
<td>C. Paleogeographic Setting</td>
<td>18</td>
</tr>
<tr>
<td>D. Depositional Model</td>
<td>18</td>
</tr>
<tr>
<td>III. FIELD METHODS AND LABORATORY PROCEDURES</td>
<td></td>
</tr>
<tr>
<td>A. Field Methods and Sampling</td>
<td>20</td>
</tr>
<tr>
<td>B. Laboratory Procedures</td>
<td>20</td>
</tr>
<tr>
<td>1. Insoluble Residue Analysis</td>
<td>21</td>
</tr>
<tr>
<td>2. Pipette Analysis</td>
<td>21</td>
</tr>
<tr>
<td>C. Procedure Reliability</td>
<td>24</td>
</tr>
<tr>
<td>IV. INTERPRETATION</td>
<td>26</td>
</tr>
<tr>
<td>V. CONCLUSIONS</td>
<td>34</td>
</tr>
<tr>
<td>VI. REFERENCES CITED</td>
<td>35</td>
</tr>
<tr>
<td>VII. APPENDIX A (Pipette Analysis Data Form)</td>
<td>37</td>
</tr>
<tr>
<td>VIII. APPENDIX B (Stratigraphic Distribution of Total Detritus (percent insoluble) and Silt/Clay Ratios)</td>
<td>39</td>
</tr>
<tr>
<td>IX. APPENDIX C (Stratigraphic Distribution of Silt/Carbonate Ratios)</td>
<td>44</td>
</tr>
<tr>
<td>X. APPENDIX D (Stratigraphic Distribution of Clay/Carbonate Ratios)</td>
<td>47</td>
</tr>
<tr>
<td>XI. APPENDIX E (Paleogeographic Setting of North America During Silurian)</td>
<td>50</td>
</tr>
</tbody>
</table>
ANALYSIS OF MISSISSINEWA SHALE-LISTON CREEK LIMESTONE CONTACT IN NORTHEASTERN INDIANA

I. INTRODUCTION

The Wabash Formation, with its encompassed Mississinewa Shale and Liston Creek Limestone Members, is a Silurian interreef deposit of late Niagaran age (Shaver et al., 1971) (figure 1). In northeastern Indiana the contact between these two members is exposed at several quarries, road, and stream cuts. Existing contemporaneously with the deposition of the Wabash Formation were numerous pinnacle reefs in addition to two major reef complexes along the edges of the Michigan and Illinois basins (Shaver, 1978). These Silurian reefs of the Midwest have been, over the last few years, the targets of petroleum exploration, and are prized as sources of crushed stone and chemical-grade carbonates. In southwestern Indiana, petroleum has been extracted from the overlying strata which are usually domed due to differential compaction of subsequently deposited layers. In some areas, such as in Michigan and Illinois, but not in Indiana as yet, petroleum has been produced directly from the reef bodies (Becker and Keller, 1976).

A. Purpose of Study

The objective of this research is to determine how the detrital component of the Wabash Formation varies in the
Figure 1. - Chart showing the evolution of nomenclature of Middle (Niagaran) and Upper (Cayugan) Silurian rocks (from Droste and Shaver, 1982, Fig. 2).
vicinity of the Mississinewa-Liston Creek contact. As early as 1927, in the work of Cumings and Shrock (1927), it was noted that there was a decrease in the silica content of the Mississinewa Member in a traverse from Yorktown to Kokomo (30.28 percent at Yorktown to 15.90 at Kokomo).

Owens (1981) further developed this issue of using terrigenous clastics as a research tool in his work on the Mississinewa Member. Owens determined two source areas for the supply of detritus to the Mississinewa shale. Figure 2, a map displaying the regional distribution of insoluble residues in the Mississinewa Member, indicates these two source areas. One of these, southeast of the Wabash Formation outcrop area, was a clay-rich source. This source was supplied via ocean currents carrying materials derived possibly from the Appalachians, or exposed Ordovician sediments in the Cincinnati area. Silt and clay from this source settled out of suspension in high concentrations in the southeast of Owens' study area (extreme southeastern Madison and Delaware counties) (figures 3 and 4). Finer silt and clay remained in suspension and was finally deposited further northwest in substantially lower concentrations.

The second of Owens' sources was a silt-rich source from the northwest (figures 3 and 4). Figure 5, a map illustrating the regional distribution of silt-clay ratios in the Mississinewa Member of the Wabash Formation, shows the greater potency of the northwestern source as a source of silt. Owens believed this source was of aeolian origin, blown into
Figure 2. - Map displaying the regional distribution of insoluble residues in the Mississinewa Member of the Wabash Formation. Notice areas of higher concentration at the northwest and southeast corners. Black dots represent localities where the entire stratigraphic sequence was sampled. Small triangles indicate sites where a single sample representative of the entire exposure was collected. Large black symbols indicate reef-proximal localities. Contour interval equals 10 percent (from Owens, 1981, Fig. 9).
Figure 3. - Regional distribution of silt in the Mississinewa Member of the Wabash Formation. Notice increased silt in northwest and southeast corners. Values represent silt content as a percentage of total lithologic composition. Black dots represent localities where the entire stratigraphic sequence was sampled. Small triangles indicate sites where a single sample representative of the entire exposure was collected (from Owens, 1981, Fig. 10).
Figure 4. - Map illustrating the regional distribution of clay as a percentage of total lithologic composition. Notice areas of higher concentration of clay at the northwest and southeast corners. Contour interval equals 5 percent (from Owens, 1981, Fig. 12).
Figure 5. - Map illustrating the regional distribution of silt-clay ratios in the Mississinewa Member of the Wabash Formation. Black dots represent localities where the entire stratigraphic sequence was sampled. Small triangles indicate sites where a single sample representative of the entire exposure was collected (from Owens, 1981, Fig. 11).
the marine waters from arid lands west of the Michigan basin. The amount of detritus, from this source, decreased to the southeast.

B. Significance

Should it be possible to determine some sort of pattern in the silt and clay components of the Wabash Formation at the Mississinewa-Liston Creek contact, it might shed light on the events that caused the abrupt lithic change at this contact. Paleocurrents, paleowinds, and paleoclimatic events might be deduced if this pattern could be applied over a large area, such as northeastern Indiana.

C. Selection of Field Localities

Silurian rocks in Indiana crop out in a broad belt in northeast Indiana, extending southward in some areas (figure 6). This general region became the basis for this study.

In order to test Owens' data, and examine the upper contact relationship of the Mississinewa with the overlying Liston Creek, four sample areas were selected. Two of these were in the vicinity of Wabash, at the northern end of the Silurian outcrop area of Indiana. Two other localities were selected at the southern edge of the Silurian outcrop belt (figure 7). The exact locations of these localities are as follows:

1. Wabash: Deep road cut on state road 13 on the south edge of Wabash, Indiana, North Reserve 55, T27N, R6E

2. Shanty Falls: 3 miles west of Wabash, Indiana, southern bank of the Wabash River, north Reserve 55, T27N, R6E
Figure 6. - Generalized geologic map of Indiana and parts of adjoining states (from Pinsak and Shaver, 1964, Fig. 1).
Figure 7. - Map of study region showing sampling localities. site 1 - Wabash, site 2 - Shanty Falls, site 3 - Noblesville, site 4 - McCordsville Study region equals approximately 470 square miles.
3. Stony Creek Stone Co., Inc., R. R. 4, Box 133A
Noblesville, IN 46060, 4 miles E of Noblesville
on S. R. 38, Riverwood Quad., SE$_1^4$NE$_1^4$ sec. 3 T18N, R5E

4. Irving Materials, Inc., R. R. 1, Fortville, IN
46140, 3.5 miles N of McCordsville on C. R. 600 W.,
McCordsville Quad., NE$_1^4$SW$_1^4$ sec. 2, T17N, R5E

It was intended that the selection of these four field
localities would permit the discovery of any possible regional
trend. By selecting two sites that were reasonably close
to each other, a limited check could be made on the accuracy
of the subsequent laboratory procedures. The choice of
localities was rather limited due to the fact that the Mis-
sissinewa-Liston Creek contact is exposed in so few places
at the surface. A more complete study would need access to
drill cores.

The southern two sites both are located in quarries.
The northern two sites lie in a region long noted for its
Silurian age deposits (Gorby, 1886; Elrod and Benedict,
1891).
Figure 7. - Map of study region showing sampling localities. site 1 - Wabash, site 2 - Shanty Falls, site 3 - Noblesville, site 4 - McCordsville Study region equals approximately 470 square miles.
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It was intended that the selection of these four field localities would permit the discovery of any possible regional trend. By selecting two sites that were reasonably close to each other, a limited check could be made on the accuracy of the subsequent laboratory procedures. The choice of localities was rather limited due to the fact that the Mississinewa-Liston Creek contact is exposed in so few places at the surface. A more complete study would need access to drill cores.

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II. GEOLOGIC SETTING

A. Structural Setting

Structurally, Indiana is dominated by two basins, separated by a system of arches. The axis of the principal arch, the Cincinnati Arch, trends northward along the Indiana-Ohio State Line, then branches, with one branch that trends northwestward, the other northeastward. In the vicinity of Cass County, the northwestern branch joins the Kankakee Arch, a southeastern extension of the Wisconsin Dome (Becker, 1974). To the northeast of this feature is the Michigan Basin, and to the southwest the Illinois Basin (figure 8). Some earlier authors such as Pinsak and Shaver (1964) termed the entire Cincinnati-Kankakee Arch system simply the Cincinnati Arch.

During the Silurian, the area between the Michigan and Illinois Basins was so broad that Shaver (1978) has termed this area the Wabash Platform (figure 9). This platform became the site of numerous pinnacle reefs. Along the margins of the platform, barrier reef complexes developed. The complex on the edge of the Michigan Basin has been termed the Ft. Wayne Bank, and the one along the edge of the Illinois Basin, the Terre Haute Bank. These banks and individual reefs have been the topic of numerous articles such as those
Figure 8. - Map of Indiana showing county names and major structural features (from Carpenter, Dawson, and Keller, 1975, Fig. 1).
Figure 9. Map of the Great Lakes area showing paleogeography and locations of some but not all known discrete reefs (dots and stars), carbonate banks or barrier reefs (stipples), and gross structural-sedimentational features, all composited for Silurian time. Individual reefs are not shown in bank areas; arrows represent reported forereef-to-backreef directions for given reefs (from Shaver, 1978, Fig. 1).
by Carrozzi and Zadnik (1959), Textoris and Carrozzi (1964), and Droste and Shaver (1980) to name but a few.

B. Stratigraphy of the Wabash Formation

The stratigraphy of the Wabash Formation and its adjacent formations have undergone a gradual evolution of nomenclature. The Mississinewa and Liston Creek Members were originally described respectively as an irregularly fractured "cement rock" of approximately 135 feet overlain by 60 feet of cherty limestone or "quarry rock" (Elrod and Benedict, 1891).

The current nomenclature for the Niagaran and Lower Cayugan Series began to take form through the work of Pinsak and Shaver (1964). They named the stratigraphic sequence for Indiana (oldest to youngest) as the Salamonie Dolomite, Waldron Formation, Louisville Limestone, and Wabash Formation.

The Salamonie Dolomite is named from the exposures of dolomite in the headwaters area of the Salamonie River in the vicinity of Portland, Jay County, in east-central Indiana. It is characteristically a light-colored medium-grained fossil-fragmental porous dolomite. The Waldron Formation in northern Indiana consists of distinctive mottled dark-gray and tan fine-grained to sublithographic argillaceous limestone or dolomitic limestone. The Louisville Limestone characteristically is tan and gray fine-to medium-grained thick-to medium-bedded fossil-fragmental limestone and dolomitic limestone. The Wabash Formation has two major subdivisions, the Mississinewa Shale Member and the Liston Creek Limestone Member. The Mississinewa Member generally is composed of gray fine-grained argillaceous silty dolomite and dolomitic siltstone and minor amounts of pyrite. The Liston Creek Member consists of a light-gray and tan fine-to medium-grained fossil-fragmental cherty limestone and dolomitic limestone (Pinsak and Shaver, 1964, pp. 24-39).

This nomenclature has been modified twice since its inception by Droste and Shaver (1976) who proposed the name
Limberlost Dolomite be used for the upper portion of the Salamonie Dolomite. This unit was formerly termed the brown upper part of the Salamonie Dolomite, but was renamed the Limberlost Dolomite due to its differing lithology. In addition,

the Limberlost Dolomite represents the onset of restrictive Salina influences within the Michigan Basin that transgressed in time onto the Wabash Platform as far south as Indianapolis (Droste and Shaver, 1976, p. 1).

Droste and Shaver (1982) further proposed the combination of the Limberlost, Waldron, and Louisville Limestone Formations under the new name Pleasant Mills Formation. This proposed regrouping is designed to reflect, considering the Great Lakes area as a whole, a complete facies relationship that existed between the evaporites of the Michigan Basin and the interbasin rocks of the Wabash Platform. The Pleasant Mills and Wabash Formations are subsequently placed in the Salina Group, a name previously applied only to the evaporites of the Michigan Basin. Figure 1 shows this gradual evolution of nomenclature.

In keeping with this new nomenclature, Droste and Shaver (1982) have extended the Wabash Formation northward into the Michigan Basin

to include all rocks in the upper part of the Salina Group, that is, those Salina rocks lying above the Pleasant Mills Formation (Droste and Shaver, 1982 p. 21).

Southwestward, the Wabash Formation is roughly correlated to the upper Moccasin Springs Formation and lower Bailey Limestone of the Illinois Basin. Figure 10 shows these correlations.
Figure 10. - Chart showing the evolution of nomenclature of Middle (Niagaran) and Upper (Cayugan) Silurian rocks (from Droste and Shaver, 1982, Fig. 2).
C.Paleogeographic Setting

During the Silurian, paleogeographic evidence seems to indicate that the Midwest region of the United States was located somewhat south of the equator at approximately 10-20° S latitude (see Appendix E). This was a period of relatively rapid continental drift, as the same region was previously located at approximately 20-30° S latitude during the Ordovician, and subsequently at 8-18° S latitude during the Devonian, and 0-10° N latitude during the Carboniferous (Habicht, 1979).

D. Depositional Model

Prior to Owens' (1981) research, the depositional model for the Silurian of Indiana was one in which terrigenous clastics were deposited from the southeast in "surges" (Shaver et. al., 1971). Shaver (1974) further stated that both the rocks and fossils in the Liston Creek interreef facies suggest an environment of higher energy and shallower water than that of the Mississinewa (Shaver, 1974, p. 946).

Several researchers have tried to use the forereef-to-backreef direction of Silurian reefs to determine the current and wind directions during their deposition. Lowenstam (1950) used the areal distribution of reef outwash and bypassed terrigenous sediments at several reefs in the Niagara archipelago (Terre Haute Bank) area of Illinois to deduce a prevailing southerly wind. Crowley (1973) in similar research on the Middle Silurian patch reefs of the Gasport
Member (Lockport Formation) in New York came to the conclusion that wind-generated currents from the northwest were responsible for the north-to-south forereef-to-backreef relationships that he found.
III. FIELD METHODS AND LABORATORY PROCEDURES

A. Field Methods and Sampling

The Mississinewa-Liston Creek contact at the four sample sites was deduced on the basis of differences in lithology and weathering profile. Once the contact was identified, samples were taken above and below the contact. Above the contact, samples were taken at six inch intervals beginning at the top of the contact itself. This was continued up section to three feet above the contact. Below the contact, samples were taken at foot intervals beginning at the base of the contact. This was continued down to three feet below the contact. A total of eleven samples was taken at each of the sampling sites.

For each sample collected, several pieces of rock were taken for a total of approximately 500 grams. Great care was taken to collect samples that were in place, not talus from higher layers, as this could badly confuse results.

B. Laboratory Procedures

Laboratory analysis was initiated with two goals in mind. The first of these was to determine the percentage of detritus in each sample. The second goal was to acquire a grain-size distribution for each sample by the pipette method of Folk (1968).
1. Insoluble Residue Analysis

Insoluble residue analyses were conducted to determine the vertical distribution of insoluble detritus above and below the contact at each site. The method used was similar to that used by Owens (1981) with some personal modifications.

The detrital analysis of each sample began with weighing out approximately 100 grams of sample. This sample was then crushed with a rock hammer to marble-sized chips. These were submerged in a 25% HCl solution, with additional acid added when needed to completely dissolve the sample. Once the carbonate was dissolved, the sample was filtered through filter paper to catch the detritus. The filtered sample was then "flushed" several times with distilled water to cleanse it of any unreacted HCl that might cause flocculation in the pipette process. The detritus was dried and weighed, and its percentage as part of the original sample weight was calculated (figure 11).

2. Pipette Analysis

Ten to fifteen gram samples of the insoluble residue derived from the dissolution process were next run through a 4Ø wet sieve in order that the sand and mud fractions might be split. It was found that almost the entire amount of each sample was less than 4Ø (silt and clay). What was not, was dried and weighed to determine the mass of the sand fraction.

Insoluble residues of the mud size range can be analyzed by the procedures outlined by Folk (1968). The core of this
Figure 11 - Insoluble Residue Procedural Flow Chart (modified from Owens, 1981, Fig. 5)
process is an equation derived from Stokes Law:

\[
T = \frac{D}{1500 \times A \times d^2}
\]

where:
- \(D\) is equal to the depth of pipette submersion
- 1500 is a constant
- \(A\) is a constant dependent upon temperature at the time of the experiment and particle density (assumed to be that of quartz)
- \(d\) is the diameter (mm) of the various particle sizes the experimenter wishes to retrieve
- \(T\) is settling time (in minutes) required for the particle to settle a given distance beneath the surface

The methodology of the procedure was to take each mud fraction that passed through the wet sieve and place it in a standard kitchen blender with additional dispersant solution. This solution had dissolved in it a calgon dispersing agent (7.4g/liter). The mud sample was then mixed for several minutes and placed in a one liter graduated cylinder.

The graduated cylinder was next allowed to set out overnight. The purpose of this was twofold. First, to see if the dispersant was of sufficient concentration, and second, so that the temperature of the water in the cylinder could equalize with the room temperature. The following morning, the cylinders (usually in groups of three) were placed in an insulated ice chest. Alequots of 25 milliliters were drawn-off
by pipette at the required times calculated by the equation given on the previous page, and placed in pre-weighed beakers. After each withdrawal, the ice chest was sealed in order that the initial temperature (the one the values for \( T \) were based on) could be maintained. The beaker was next dried in an oven and weighed. The mass of the dried sample was multiplied by 40 (because the 25 milliliter alequot was \( 1/40 \)th of the whole liter) to find the mass of particles still in suspension. The difference in mass between two successive alequots corresponds to an entire \( \theta \) size which has settled out of suspension. (figure 12). A sample data sheet is found in Appendix A.

C. Procedure Reliability

Two preparations of each rock sample were processed. The data from these two trials were then compared for discrepancies. This means that a total of 88 trials were run through the above-described procedure.
Weigh Sand-Size Fraction

10-15 Gram Sample → Add Dispersent Solution and Blend → Wash through Wet Sieve → Place in Graduated Cylinders → Check Dispersion Effectiveness.

↓

Stir and Initiate Timing

↓

Calculate Cumulative Percentages

↓

Plot Distributions on Log-Probability Paper

Figure 12. - Pipette Analysis Procedural Flow Chart (modified from Owens, 1981, Fig. 6)
IV. INTERPRETATION

The data generated from laboratory analysis was used to construct a series of graphs. In the plotting of these graphs (see Appendixes B-D), along the ordinate was placed the relative position of the sample above or below the Mississinewa-Liston Creek contact. Each foot interval over which the samples were taken was given a constant interval on the graph. This interval was also used to separate the sample taken below the contact from the one taken above the contact for an emphasis of the contact itself.

All four sequences of Mississinewa-Liston Creek samples show some decrease in detrital content as the contact is approached. The site that shows the least decrease in percent detritus is the McCordsville site, which is the site nearest the clay-rich source area southeast of the study area. The other sites showed a much greater decrease in detritus at the contact, especially the northern two sites near Wabash (see Appendix B).

The silt/clay curves for the sites show a less pronounced pattern (see Appendix B). At three of the sites (Wabash, Shanty Falls, and Noblesville) there is a general decrease in the ratio up section. At the McCordsville site, the ratio actually increases somewhat above the contact.
When the silt and the clay content for the four sites are plotted against the carbonate content (that is assuming that the parameter of carbonate production is somewhat constant) an interesting pattern emerges (see Appendixes C and D). The northern two sites show almost no silt after Mississinewa deposition stops. The southern two sites, Noblesville and McCordsville, show a somewhat higher level of silt versus carbonate, but these higher levels characteristically appear in surges at different distances above the Mississinewa-Liston Creek contact. The clay versus carbonate of these two southern sites also show surges in clay content. These increases in clay at Noblesville and McCordsville occur in the same samples as do the surges in silt, and again, the McCordsville site shows somewhat higher levels than that of the Noblesville site. The clay versus carbonate curves of the northern two sites, Wabash and Shanty Falls, show generally uniformly low levels after the end of Mississinewa deposition.

A further analysis of the data was made by constructing, for each sample, a grain-size distribution curve on probability paper. A comparison of these curves was made to that of a cumulative grain-size distribution of a loess deposit, the type of curve match on which Owens (1981) based his theory of aeolian transport (figure 13). The curves of those samples below the contact closely matched the loess deposit curve, those above the contact did not.

It is this author's interpretation that after the end of Mississinewa deposition, the supply of northern silt
Figure 13. - Comparison of cumulative grain-size distributions of a loess deposit, Nemaha County, Kansas (after Swineford and Frye, 1945) to those of samples below and above the Mississinewa-Liston Creek contact.

- cumulative grain-size distribution of a loess deposit
- typical cumulative grain-size distribution below Mississinewa-Liston Creek contact
- typical cumulative grain-size distribution above Mississinewa-Liston Creek contact
stopped. This is suggested by both the detritus and cumulative grain-size distribution curves. What is left of the terrigenous clastic supply is being supplied in surges from the southeastern clay-rich source only. The bulk of this material settles out of suspension long before it reaches the northern two sites of Wabash and Shanty Falls. In fact, a great portion of silt-sized particles settled out between the sites of McCordsville and Noblesville.

Why did aeolian transport of the silt-rich source to the northwest cease? A simple solution to this would be vegetation growth in the source area slowing the rate of erosion. Such vegetative cover could have been provided by lichens, of which Blatt, Middleton, and Murray (1980) stated,

> it seems reasonable to suppose that the ability of lichens to grow on bare rock is related to their occurrence as one of the earliest colonizers of land in the Silurian Period (Blatt, Middleton, and Murray, 1980, p. 251).

A more satisfactory solution would be to model the wind patterns of the Silurian after existing wind patterns of today. If we accept a paleogeographic setting of 10-20° S latitude for the Midwest of the United States, this would place the study area in the monsoonal region (figure 14). The monsoonal region refers to a region where

> surface winds flow persistently from one quarter in the summer and just as persistently from a different quarter in the winter (Ramage, 1971, p. 1).

Ramage (1971) further states that,

> monsoons blow in response to the seasonal change that occurs in the difference in pressure—resulting from the difference in temperature—between land and sea. Where continents border oceans, large temperature
Figure 14. - Illustration of monsoonal regions. Hatched areas are monsoonal, heavy line marks northern limit of the region within the Northern Hemisphere with low frequencies of surface cyclone-anticyclone alternations in summer and winter. Rectangle encloses the monsoon region. (from Ramage, 1971, Fig. 1.2)

Figure 15. - Silurian paleogeography of the Great Lakes area A, Late Wenlockian to early Ludlovian (Niagaran) time. B, Pridolian (Cayugan) time (from Shaver, 1978, Fig. 23)
differences and hence large differences in pressure might be expected. However, the shapes of continents and their topographies, as well as variations in sea- surface temperatures, all interact to produce considerable regional and temporal variability in the monsoons. (Ramage, 1971, p.8).

During the summers in monsoonal regions, land masses heat-up more rapidly than do the nearby bodies of water, and subsequently become areas of low pressure; such a region is termed a cyclone. The wind direction of a cyclone is counterclockwise in the Northern Hemisphere, clockwise in the Southern Hemisphere. During the winter, the same land masses cool-off more rapidly and become areas of high pressure; such a region is termed an anticyclone. The wind direction of an anticyclone is clockwise in the Northern Hemisphere, counterclockwise in the Southern Hemisphere (Ramage, 1971).

Desert regions are excellent examples of regions that seasonally change temperature. Just such a region is theorized by Shaver (1978) to have existed to the northwest of the study area (figure 15). This desert region, along with a paleogeographic setting of 10-20° S latitude would suggest a modeling of the Silurian in this area after the present Eastern Africa and Western Indian Ocean region.

The African continent spans the equator and so in January radiational cooling results in high pressures over the Sahara and Arabia; radiational heating results in low pressure over the Kalahari Desert. The consequent north-south pressure gradient sets up a flow of air from north to south across the equator. The most intense heat lows overlie deserts and occupy the same latitude over the oceans. In contrast to January, radiational cooling results in high pressure over the Kalahari Desert, and radiational heating, in low pressure over the Sahara.
The south-north pressure gradient sets up a southerly flow across the equator, eventually merging with the southeast trades over the southern Indian Ocean and with the southwest monsoon north of the equator. The upwelling effect, mentioned above contributes to the southerly monsoon being stronger than the northerly monsoon of January (Ramage, 1971, pp 11-16).

This seasonal variation in wind, besides being an excellent model, might explain the differences in wind direction cited by Lowenstam (1950) and Crowley (1973). At the close of Mississinewa deposition this seasonal variation in wind must have been disrupted by continental drift or some other mechanism.

The southeast current needed to supply detritus from the clay-rich source to the southeast of the study area would also exist in the Eastern Africa and Western Indian Ocean region. Figure 16 shows a clockwise current existing in the Indian Ocean today that would fit nicely.
Figure 16. - Present world distribution of arid zones and ocean currents. Solid arrows-cold currents, dashed arrows-warm currents, dotted areas-deserts, diagonal lined areas-steppes (from Habicht, 1979, Fig. 3).
The Mississinewa-Liston Creek contact represents a change in the depositional environment in the northeastern Indiana region. It represents the transition of an area being supplied by two terrigenous clastic sources, to an area being supplied by only one source. The events that triggered this change are only conjecture upon the part of this author. Possible explanations for this change are changes in the wind pattern caused by continental drift, or vegetation growth in a terrestrial source area that existed to the northwest.
VI. REFERENCES CITED


Appendix A

Pipette Analysis Data Form
**Pipette Analysis Data Form**

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<th>SAMPLE NO.</th>
<th>LOCATION</th>
<th>EXPERIMENTER'S NAME</th>
<th>REMARKS</th>
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**Temperature**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Concentration of Dispersent</th>
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<tbody>
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<table>
<thead>
<tr>
<th>$\varnothing$ diam.</th>
<th>depth (cm)</th>
<th>time</th>
<th>beaker no.</th>
<th>sample and</th>
<th>beaker</th>
<th>sample wt.</th>
<th>wt.</th>
<th>$X_{40}$</th>
<th>cum.%</th>
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<tbody>
<tr>
<td>$\geq 4$</td>
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<tr>
<td>$&lt; 4$</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>$&lt; 5$</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>$&lt; 6$</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>$&lt; 7$</td>
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<td></td>
<td></td>
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<tr>
<td>$&lt; 8$</td>
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<tr>
<td>$&lt; 9$</td>
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<td>$&lt; 10$</td>
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**Weight Obtained by Wet Sieving**

- $S$: weight
- $(S+F)$: total weight
- $(F-P)$: weight difference

\[
\frac{100(S+(F-P))}{S+F}
\]
Appendix B

Stratigraphic Distribution of Total Detritus (percent insoluble) and Silt/Clay Ratio
Shanty Falls

Trial #1

Trial #2

Location

Percent Detrital

Silt/Clay

3 Feet Above
2 Feet Above
1 Foot Above
Above Contact
Below Contact
1 Foot Below
2 Feet Below
3 Feet Below

0.3 0.6 0.9 1.2 1.5 1.8 2.1

Silt/Clay

0.3 0.6 0.9 1.2 1.5 1.8 2.1
Appendix C

Stratigraphic Distribution of Silt/Carbonate Ratios
Appendix D

Stratigraphic Distribution of Clay/Carbonate Ratios
Appendix E

Paleogeographic Setting of North America During Silurian