MARINE BENTHIC COMMUNITIES OF THE READING LIMESTONE (UPPER PENNSYLVANIAN) ATCHISON COUNTY, KANSAS

by

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INTRODUCTION

Purpose of Investigation

Principle objectives of this study were: (1) to identify depositional environments of the Reading Limestone Member of the Emporia Limestone (Upper Pennsylvanian, northwest Atchison County, Kansas); (2) to identify associated fossil communities; (3) to relate changes between depositional environments and "fossil communities"; and (4) to relate depositional environments, ecologic parameters and functional morphology of community members.

This area was selected because of the diversity and abundance of well preserved, relatively undisturbed fossil assemblages, distinct lithologic boundaries, and accessibility.

Location

The area is in the spillway of the Atchison County Park Dam, Atchison County, Kansas (Sec. 12, T.5 S., R. 17 E.). Horton, Kansas, approximately five miles to the northwest, is the nearest city.

Previous Investigations

The Emporia Formation was originally named by Kirk (1896) for exposures at Emporia, Kansas and consists, in ascending order, of the Reading Limestone Member, Harveyville Shale Member and Elmont Limestone Member. Smith (1905) named the Reading Limestone; Moore (1936) placed the type locality near Reading in Lyon County, Kansas. The Harveyville Shale was first described by Moore (1936) from exposures near Harveyville in southeastern Wabaunsee County, Kansas. Beede (1898) named the Elmont Limestone for the town of Elmont in northern Shawnee County, Kansas.

Regional Setting

The area is east of the axis of the Forest City Basin on the east flank of the Nemaha Anticline (fig. 1). Locally the Redfield Anticline (southeastern corner of Nebraska) was a minor structural feature.

Strata of the Wabaunsee Group (Virgilian Stage) crop out in Kansas in two distinct parallel belts: along the crest of the breached Nemaha Anticline, exposed predominately in Pottawatomie and Nemaha Counties; and in a band 10-20 miles wide striking northeast-southwest (fig. 2). This group is dominated by shales, but limestones are persistent, uniformly thin, averaging two to three feet in thickness. Most of these strata are covered, north of the Kansas River, by extensive glacial deposits (Moore, 1936).

The Reading Limestone Member strikes N 39°W and dips 0.62°S, 51°W and is concordant with the underlying Auburn Shale and overlying Harveyville Shale (fig.3). According to Moore (1949), the most persistent subdivision of the Reading Limestone Member is a fusulinid-bearing unit consisting of four beds of dark blue, fine-grained, dense, hard limestone with prominent vertical joints. A limestone bed containing many bivalves and some brachiopods occurs in some outcrops below this fusulinid-bearing limestone.

Bayne and Schowe (1967) found, that in adjacent Brown County, the lower limestone is soft, bluish-gray and 0.5 to 1.0 foot thick, with a brachiopod and Wilkingia assemblage. Overlying the lower limestone is a unit of thin bedded gray shale, rarely exceeding one foot thick. This shale underlies the previously described fusulinid-bearing unit. Total thickness of the Reading Limestone in Brown County ranges from 4.5 to 6.5 feet.

South in Shawnee County, the Reading Limestone Member of the Emporia Limestone thins and the middle shale is absent (Johnson & Adkison, 1967). In southeastern Kansas, this shale contains a coal bed. In Oklahoma the Emporia

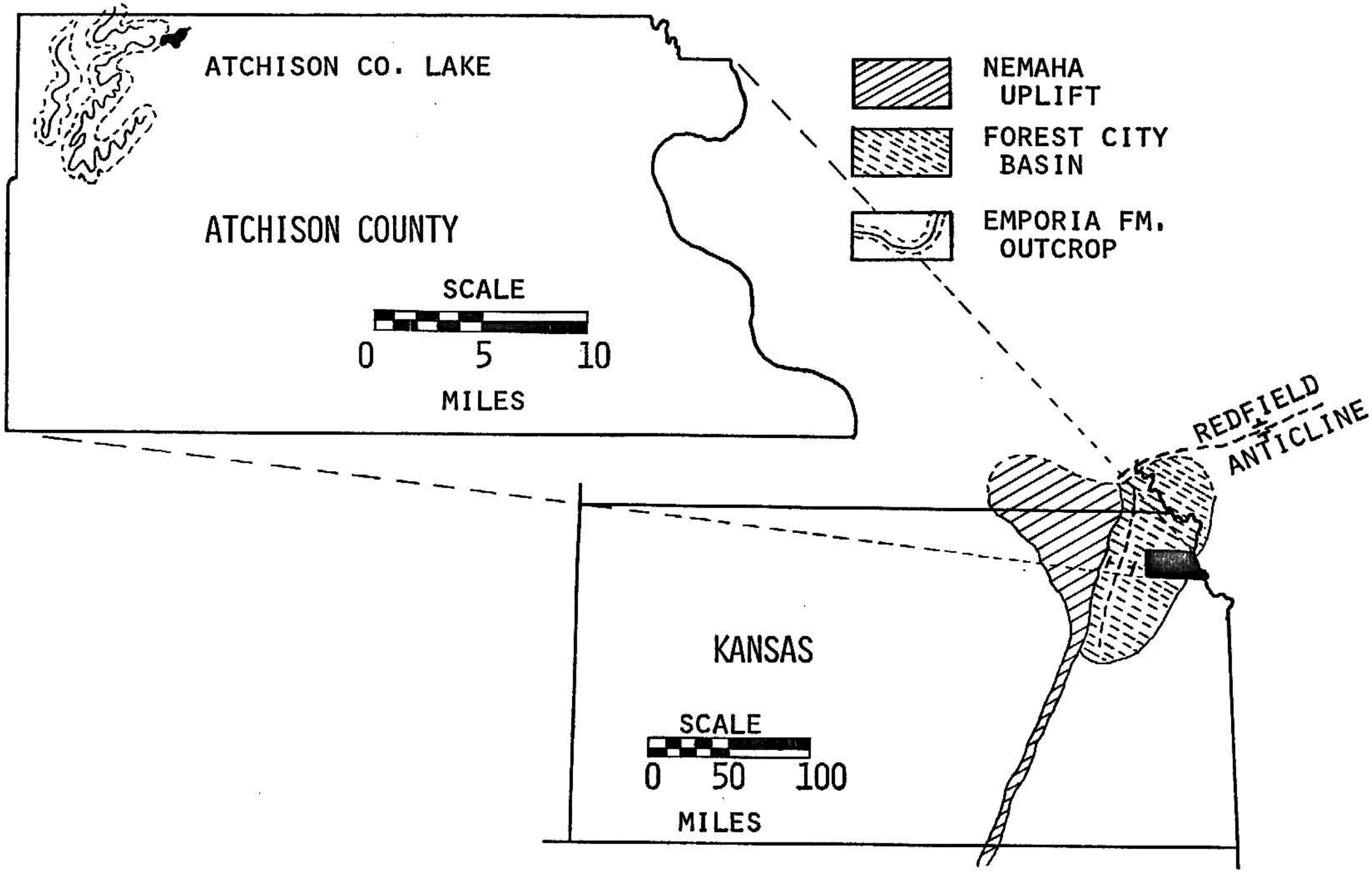

Figure 1. Geologic Setting of Study Area.

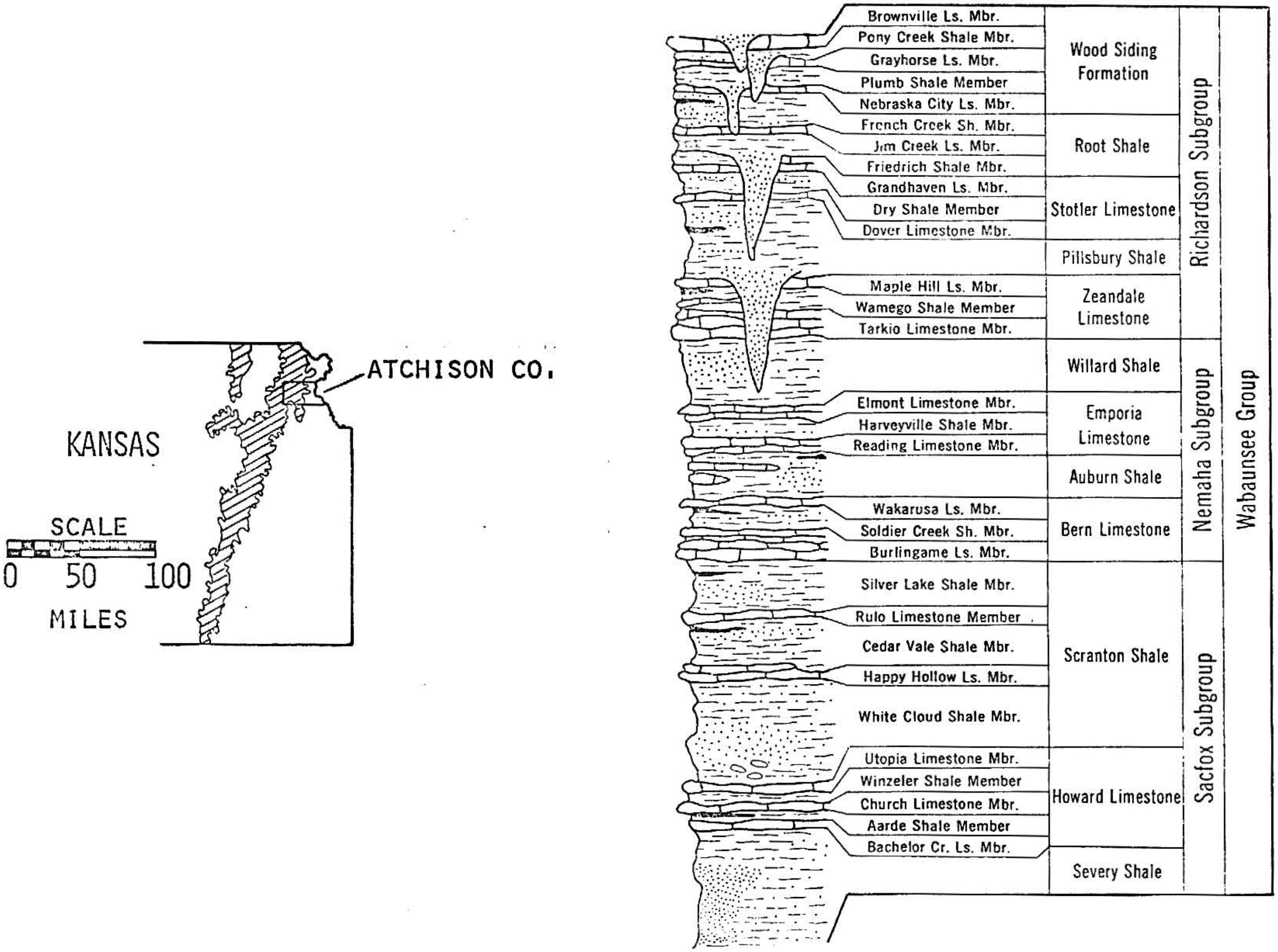

Figure 2. Areal Distribution (Merriam, 1963) and Rock Column (Zeller, 1968) of Wabaunsee Group in Kansas.

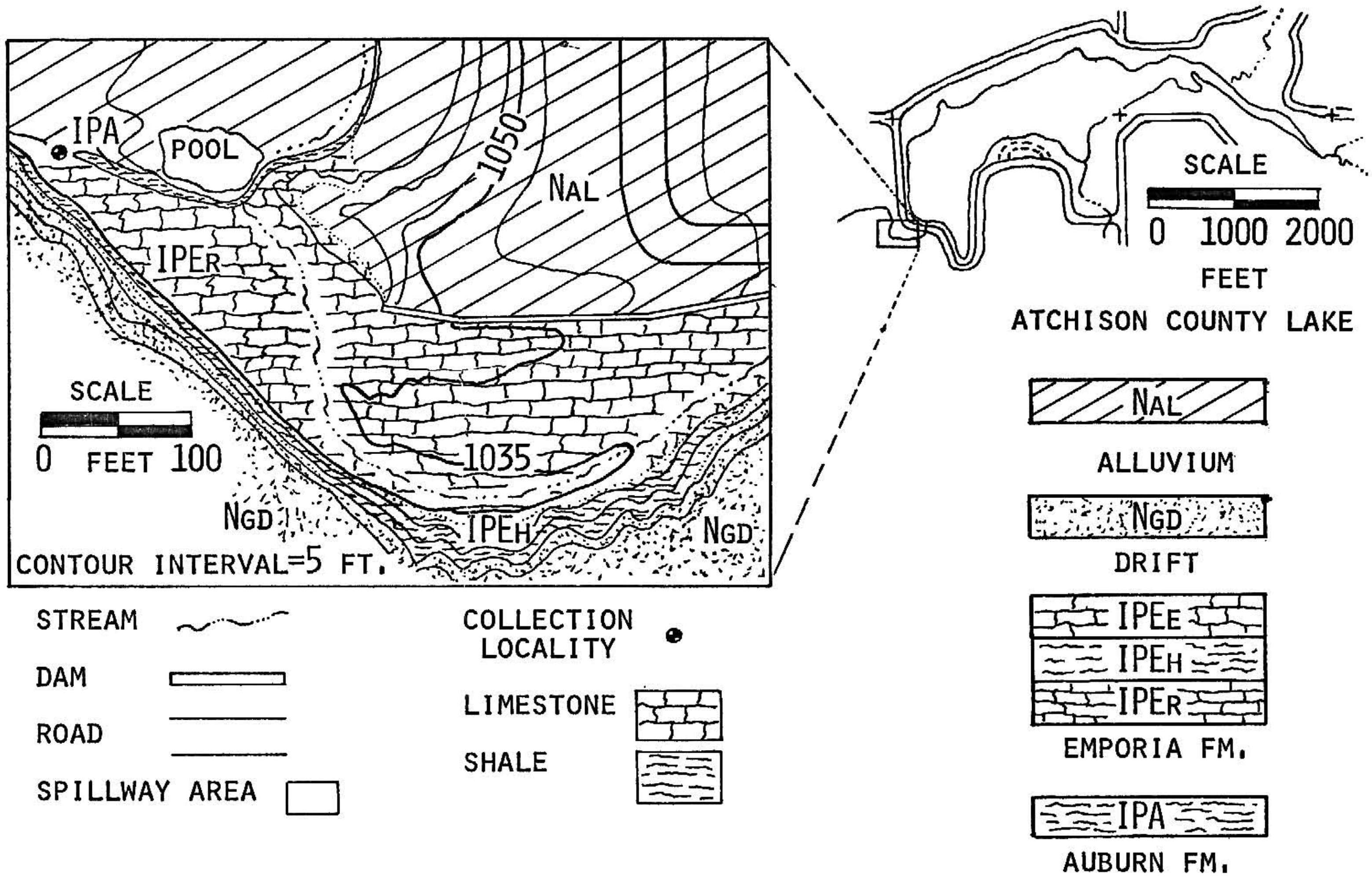

Figure 3. Geologic Map of the Spillway Area.

Formation correlates with the Stonebreaker Limestone; northward (Nebraska) the nomenclature remains the same (Moore, 1949).

METHODS OF INVESTIGATION

Field Procedure

Sequence of field procedures is illustrated by a flow chart (fig. 4). Using the dam as a bench mark, a topographic map and geologic cross section (fig. 5) were constructed using plane table and alidade. A line parallel to the maximum amount of exposed section through stations 14 and 18 (fig. 5) was established. Each decimeter along this line was numbered and using a random number table, one of the numbered decimeters (station 18) was selected. Lithologic and biologic collections were made of the full vertical section of the Reading Limestone at station 18. Spot samples were collected from the Harveyville Shale and Elmont Limestone (station 33) and from the Auburn Shale (station 22) on both sides of distinct lithologic breaks and near the middle of the exposed units. Criteria for collection of field samples from the underlying and overlying units were that they be fresh, unweathered, in place, 1000 to 2000 gram samples from a narrow 10 mm to 20 mm stratigraphic interval.

Samples of each limestone bed of the Reading Limestone were numbered (fig. 9), "up" direction indicated, wrapped in newspaper and removed to the laboratory. Siltstones were cut into twelve inch cubes, numbered, "up" direction indicated, wrapped in burlap and removed to the laboratory where they were encased in plaster to prevent crumbling. Over one thousand pounds of the Reading Limestone were collected for laboratory preparation and study.

Oriented specimens of *Wilkingia* and *Pteronities* with enclosing matrix were also collected. Samples were supplemented with photographs of outcrop

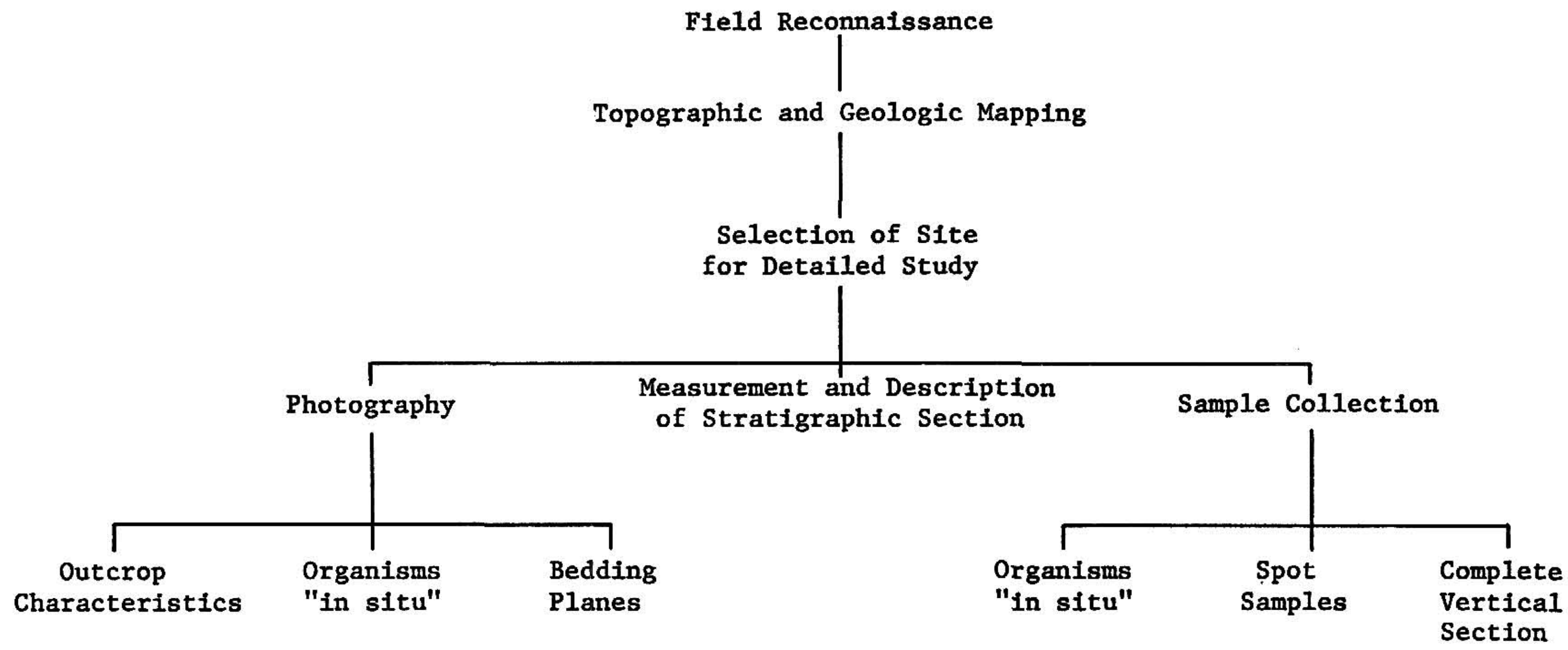

Figure 4. Flow Chart of Field Procedure.

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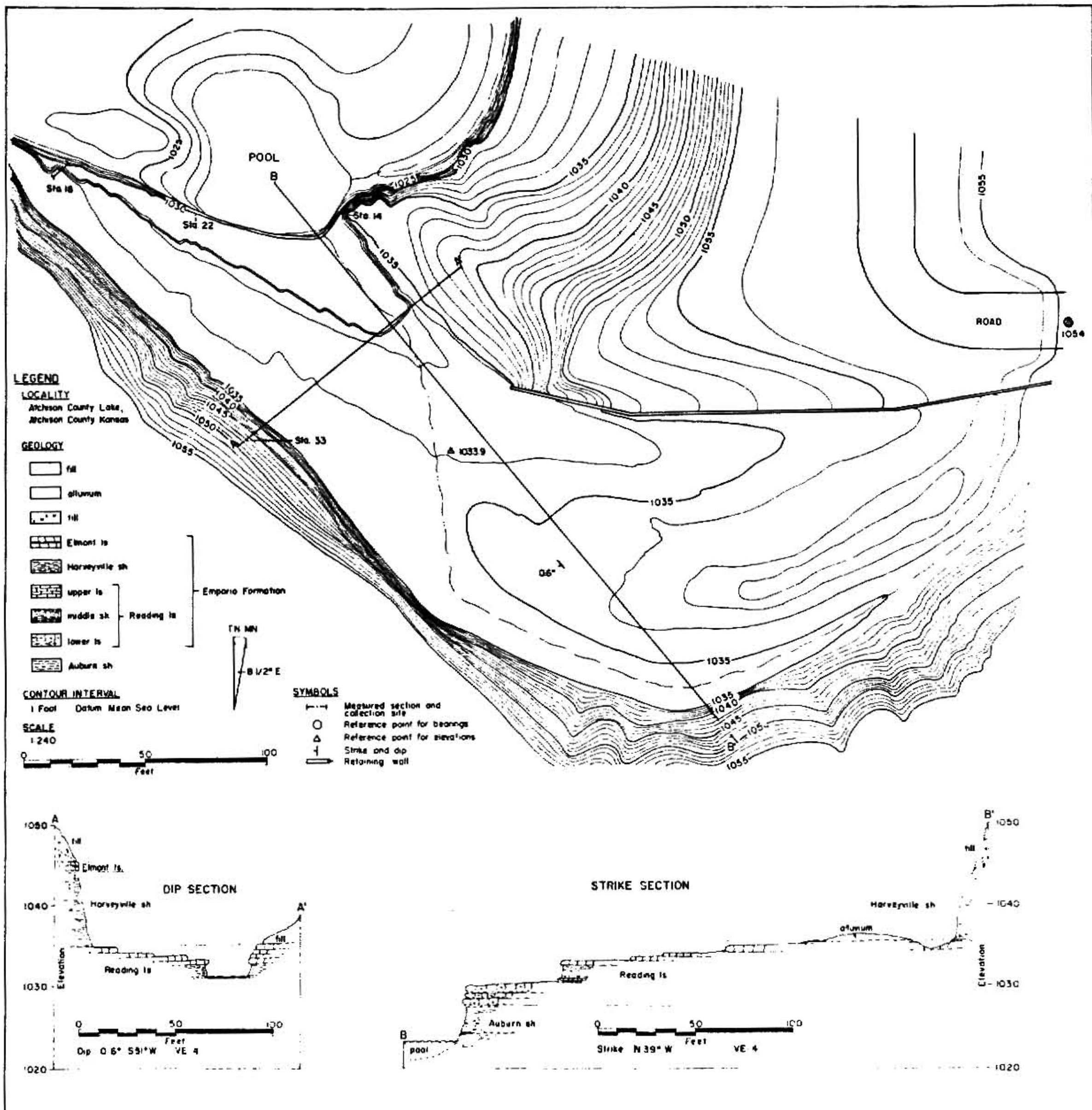


Figure 5. Topographic map and cross sections of the Atchison County Lake spillway

characteristics, "in situ" macrofossils and bedding planes to aid in laboratory study.

Laboratory Procedure

General Statement.--A total of sixty eight field samples were collected from which thirty nine laboratory samples were analyzed (table 1). As the principle objective was a detailed study of the Reading Limestone, samples exclusive of the Reading Limestone were examined only for their content of insolubles. This aided in establishing the depositional cycle of which the Reading Limestone is a part. A flow chart of laboratory procedures is in figure 6.

Disaggregation.--Siltstones of the Reading Limestone, units 4, 6 and partings in the lower limestone (2b and 3b) were disaggregated and fossils sorted, identified, and counted. Field sample of bed 6 was divided into two laboratory samples, 6-b at the base and 6-m (middle), 9.6 inches above the basal contact. Later it become evident that for insolubles analysis, it would be necessary to divide bed 6 into three samples 6-b, 6-m and 6-t (6-t representing the top 1-2 inches of bed 6).

Samples weighing 1000-2000 grams were prepared by (1) drying in an oven, (2) soaking in kerosene for 24 hours, (3) draining the kerosene, and soaking in boiling water for another 24 hours, (4) washing the disaggregated sample through a 230 (4 Ø) mesh seive with hot water and (5) oven drying at 450°C. After drying, the residues were dry seived through ten mesh (-1.00 Ø), 18 mesh (0.00 Ø), 35 mesh (1.00 Ø) and 60 mesh (2.00 Ø) seives. Where the seived fraction was large, a sample splitter was used to reduce it to a manageable size for separation and identification. Fossils in the +10, +18 and +35 fractions of each sample were sorted, identified to genus and counted.

Table 1

Samples from the Emporia Formation

Field Samples:

Type	Elmont Limestone	Harveyville Shale	Reading Limestone	Auburn Shale
Lithologic	2	2	-	3
Biologic	2	2	-	3
Composite*	-	-	12	-
Life Position	-	-	42	-

Laboratory Samples:

Type	Elmont Limestone	Harveyville Shale	Reading Limestone	Auburn Shale
Radiography	-	-	80	-
Etched Section	-	-	7	-
Disaggregation	-	-	5	-
Thin Section	-	-	11	-
Bedding Plane	-	-	3	-
Insoluble Residue	2	2	15	3
X-Ray Diffraction and Spectroscopic Analysis	-	-	11	-

*Lithologic and biologic.

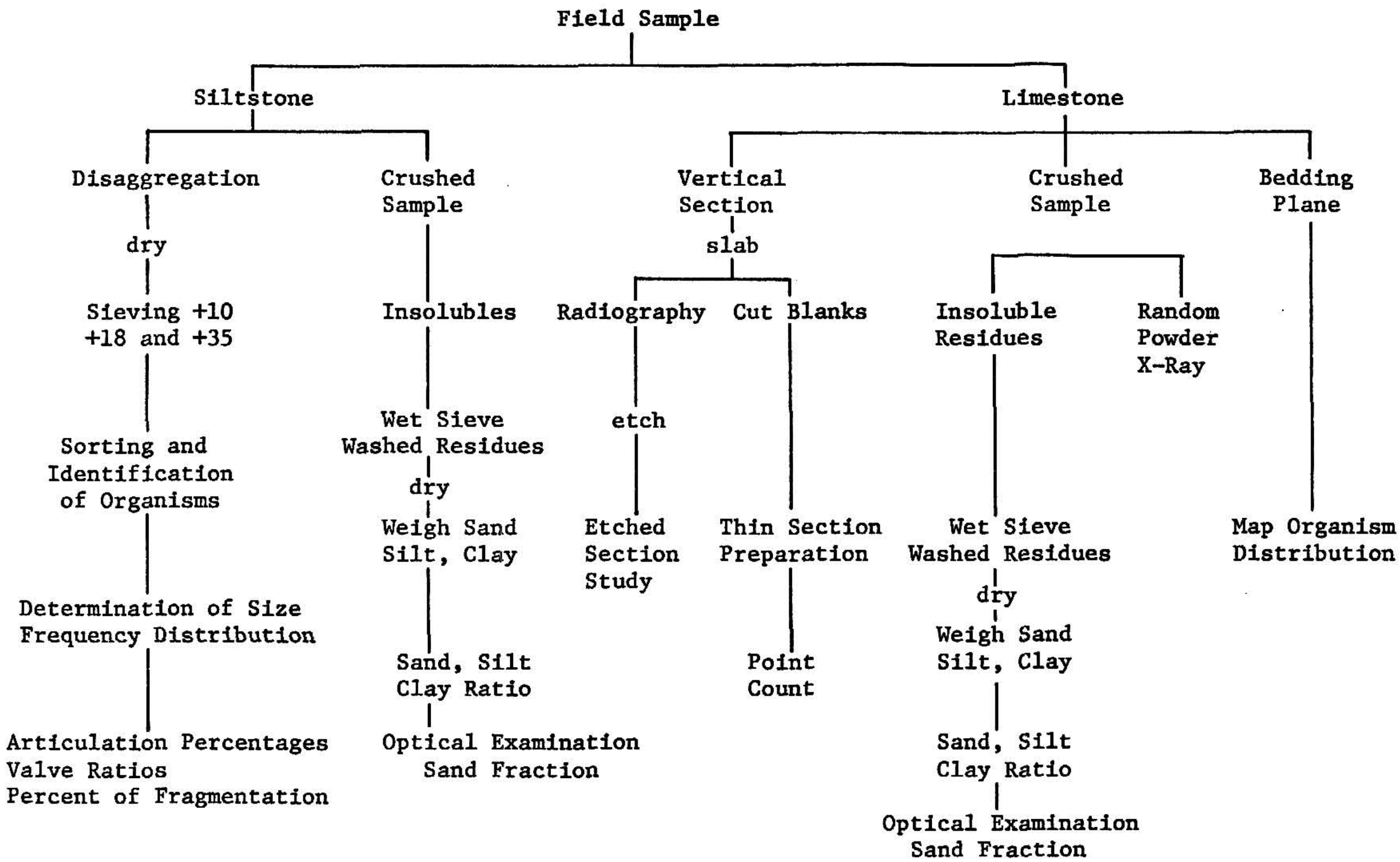


Figure 6. Flow Diagram of Laboratory Procedure.

These data are tabulated in Appendix 2. Where preservation permitted, size frequency distributions, articulation percentages, valve ratios and percents of fragmentation were constructed and/or calculated.

Etched Vertical Sections.--Slabs one centimeter thick and ten centimeters square were cut from the seven samples representing the full thickness of beds 1, 2, 3, 7, 8, 9 and 10. These vertical sections were polished, etched in 2N hydrochloric acid for one minute and washed in water. On each slab a 20 mm wide vertical section was divided into successive 20 mm squares for microscopic investigation. Megafossils were identified and sketched according to their position in the slab. Lithologic textures and structures and frequencies of mega and microfossils were noted. Appendix 3 is a tabulation of these data.

Bedding Plane Study.--The most direct inference of life habits of extinct organisms is to observe them preserved in or near presumed life position (Raup and Stanley, 1971). Bedding planes at the contact of units 6 and 7, the middle portion of unit 4 and the upper surface of unit 3 were studied.

Sample preparation consisted of spraying the bedding plane with krylon, photographing and/or mapping distribution of fossils (bed 4 and the contact between beds 6 and 7) and substrate variations in one square decimeter. Maps of these surfaces illustrating spatial distribution of organisms and the substrate are in Appendix 4a. Bedding plane data from this and the study by Pearce (1973), are tabulated in Appendix 4b.

Radiography.--Radiographic study is based on differential passage of x-radiation through a sample onto x-ray film. Intensity of x-rays is a function of sample composition, sample thickness and initial radiation intensity. Intensity differences during passage are recorded as differences in photographic density (Bouma, 1969). Therefore, radiography provides a means of studying organism-substrate relationships without destroying the sample, provided of course, that compositional differences exist between the fossil skeleton and the enclosing rock. The original intent was to radiograph a vertical sequence of the entire thickness of the Reading Limestone. Samples from each unit were cut into 10 vertical sections, 0.9 cm thick and a decimeter wide. Access to an industrial x-ray unit was obtained and slabs from units 3 and 9 were radiated using different exposure times. Machine settings for the tests were 60 Kv, 5 milliamps, with a focal length of 30 inches and exposure times of 1, 2 and 3 minutes. Test values for carbonate rocks were arrived at by consulting Fraser and James (1969). Kodak Industrial Film, Type M was used because it is a slow, fine grained film which provides detailed radiographs. Exposed film was developed five minutes at 22^{o}C in Kodak Industrial Film Developer, fixed ten minutes in Kodak Industrial Film Fixer (22^{o}C) washed twenty minutes in water and air dried for one hour.

Best contrast and detail appeared on radiographs using an exposure time of three minutes; however, it was not possible to differentiate adequately between fossils and matrix because of inadequate compositional differences.

Thin Section Analysis.--Thin sections from beds 1, 2, 3, 5, 7, 8, 9 and 10 were studied to determine grain parameters, mineralogical composition and microfossil identity. Bed 10 was further subdivided into top (10-t), lower top (10-lt), upper base (10-ub) and base (10-b). Up direction and identification number were marked on 30 by 50 mm by 1 cm thick blanks cut from each sample. Thin sections (27x46 mm) of each blank were prepared by a commercial firm (Hillquist).

An area 20 by 30 mm on each slide was examined in millimeter increments (600 points total), using a petrographic microscope equipped with a mechanical stage. Each of the 600 points represents the intersection of the crosshairs on a lithologic and/or biologic component. At each point, the component was identified (orthochemical, allochemical or terrigenous), typed (micrite, microspar, spar, intraclast, bioclast, pellet, ooid, etc.) and sized (measurements were made with an ocular micrometer). Only 600 points were used because counting error is below variation for orthochemical components of limestones and 600 points provided coverage of the total slide area. Rock names for the carbonate beds are according to Folk (1968).

Orthochemical constituents are:

<u>Micrite</u> Microcrystalline, calcite ooze cement, grains 1-4 microns in diameter, subtranslucent in thin section, partly produced by inorgainc causes (heating, evaporation or agitation) and partly produced by orgainc causes (algae, bacteria, etc.) and presently forming over the protected calm waters of the Bahamas.

<u>Microspar</u> Coarser micrite, equidimensional uniform, 5-10 microns in diameter, probably represents aggrading recrystallization of micrite matrix, occurs in thin section as irregular patches which grade into areas of micrite.

<u>Spar</u> Calcite cement, grains or crystals 10 microns or more in diameter, distinguished by clarity and coarseness in thin section and thought to be pore filling cement where micrite has been washed out.

Fossils are the only allochems observed in thin sections though intraclasts, ooids and pellets are also allochemical constituents. Thin section data are tabulated in Appendix 5.

<u>X-Ray Diffraction</u>.--Random powder x-ray analysis was used to identify non-clay minerals in units 1, 2, 3, 5, 7, 8, 9 and 10. A flow sheet (fig. 7) indicates sample preparation. Diffractometer settings were: (1) chart speed, 30 inches per hour, (2) scanning speed 1° per minute, (3) target, Ni, filtered Cu K alpha, (4) divergent and antiscatter slit, 1°, (5) receiving slit, .003 inch, (6) kilovoltage setting, 35, (7) millamperage, 18, and (8) time constant

Raw Sample

weigh

10 Gram Sample

mortar and pestle

Finely Powdered Sample

dry sieve (230 mesh) 4 ϕ

-230 Fraction

label

Storage Bottles

mount in
aluminum frame

Mounted Random
Powder Slide

x-ray; 0^{o}-62^{o}

Figure 7. Flow Diagram of Procedure for Random Powder X-Ray Analysis.

2 seconds. A scale factor of 1 K gave the required detail. Samples were scanned from 0-90° to determine major peak positions and for record, were run from 0-62°. Appendix 6 contains x-ray diffraction data.

Spectroscopic Analysis.--Spectroscopy was used to determine quantities of iron, manganese and magnesium in samples 1, 2, 3, 5, 7, 8, 9 and 10. Approximately 25 milligrams of powder (from the excess powder of x-ray diffraction analysis) were placed in the ceramic hearth. The sample was then placed in a Vreeland Model 6-A spectroscope for analysis. Detailed operating instructions of this spectroscope are provided with each instrument (Operating Instructions: Vreeland Model 6-A Spectroscope).

Progressive heating of a sample on a disposable refractory hearth causes successive excitation of the spectra of elements. These spectra are projected through an optical system onto two films, a master film and an elimination film. Comparison of the observed spectra with these films allows semi-quantitative estimation of the relative quantities of the elements in the sample. Appendix 7 contains the data from these analyses.

Insoluble Residue.--The procedure for obtaining insoluble residues in this study, is a modification of the original (McQueen, 1931) and follows closely that used by Huber (1965). An outline of the procedure in shown by a flow sheet (fig. 8).

A 200-250 gram sample was crushed in the rock crusher to pea-size or smaller. Twenty grams of oven dried sample were placed in an 800 ml beaker. Siltstone samples, before going into the beaker, were placed in a blender with 600 ml of distilled water and mixed for ten minutes. Before adding acid, each sample was moistened with 50 ml of distilled water to diminish initial violence of the acid reaction. One hundred millimeters of 6 N HCl was added slowly and the reaction allowed to proceed 15-30 minutes. An additional 100 ml of

PROCEDURE

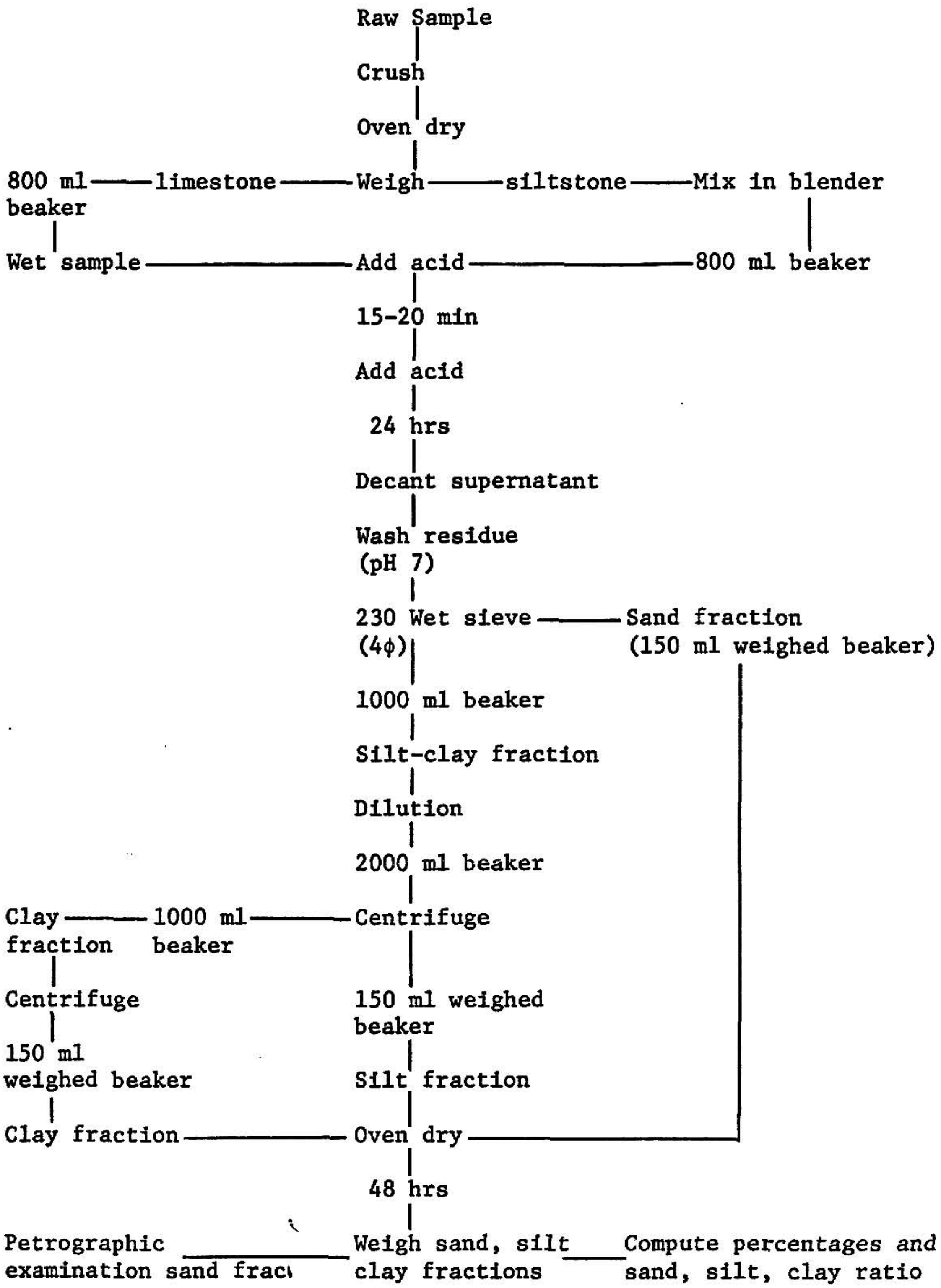


Figure 8. Flow Diagram of Insoluble Residue Analysis.

acid was added and allowed to stand for 24 hours to allow complete solution of all solubles. The acid and residue were washed (5 times minimum) until a pH of 6.5-7.0 was obtained from the supernatant. A 230 mesh (4 Ø) seive was used to wet seive the sample, thereby separating the sand from the silt-clay fraction. The silt-clay fraction was retained in a 1000 ml beaker, while the sand fraction was transferred to weighed (nearest .001 gram) 150 ml beakers. To eliminate the possibility of flocculation in the silt-clay fraction, it was diluted further with 1000 ml of distilled water and retained in a 2000 ml beaker. This solution was allowed to stand for 24-48 hours to observe any flocculation, if flocculation occurred, the solution was diluted until all flocculation ceased. To separate the clay fraction (less than 2 microns) from the silt fraction, the silt-clay fraction was centrifuged in 100 ml tubes. Each tube was filled, with the silt-clay solution, to a depth of ten centimeters with distilled water, the room temperature was checked, temperature correction in centrifuge time computed and centrifuged (Jackson, 1958). The supernatant containing the less than 2 micron fraction in suspension was poured into a 500 ml beaker before centrifuging again to remove the water. The clay residue and the silt fraction were transferred to separate 150 ml weighed beakers. The sand, silt, and clay residues were then placed in the oven for 48 hours to dry, removed and weighed (to the nearest .001 gram, see Appendix 8). After weighing, the sand fraction was examined petrographically using the oil immersion method. An oil index of 1.53 was used to aid in distinguishing orthoclase from quartz (quartz with a low index of 1.54 shows positive relief, while orthoclase with a high index of 1.526 shows negative relief). Fifty grains per sample were examined under reflected and polarized light. Long and short dimensions were measured, sphericity, roundness and color noted, inclusions and extinction type identified. Data from optical study of the insolubles are contained in Appendix 9.

STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS

General Statement

The Reading Limestone Member of the Emporia Limestone can be divided into three units, an upper limestone, middle siltstone and lower limestone (fig. 9). Joint systems are in both limestones but are most conspicous and better developed in the upper limestone. In the south wall of the spillway channel, 10.8 feet of Harveyville Shale overlie the upper limestone and 1.9 feet of lower Elmont Limestone overlie the Harveyville Shale. The remainder of the interval along the south wall is glacial till. Underlying the lower Reading Limestone are four feet of Auburn Shale.

Depositional environments during Reading Limestone time can be inferred using tectonic framework, rock type (i.e. substrate character) and mineralogical components. Three key elements from laboratory analysis of lithologies, provide the basis for environmental interpretations: (1) carbonate type (micrite, microspar, spar), (2) carbonate mineralogy (calcite, dolomite) and (3) insolubles (percent sand, silt and clay).

Carbonate Type.--Utilizing grain size, fossil and mineralogical data from thin section study and applying Folk's (1968) carbonate classification limestones of the Reading Limestone are biomicrites. Folk (1968) also provided the basis for recognizing the environmental significance of biomicrites. Biomicrite is a Type II (microcrystalline allochemical rock) limestone. Type II limestones are indicative of weak, short lived currents, or a rapid rate of micrite formation. Micrite represents a clay size matrix, which implies poor washing and energy levels insufficient for winnowing. Such conditions

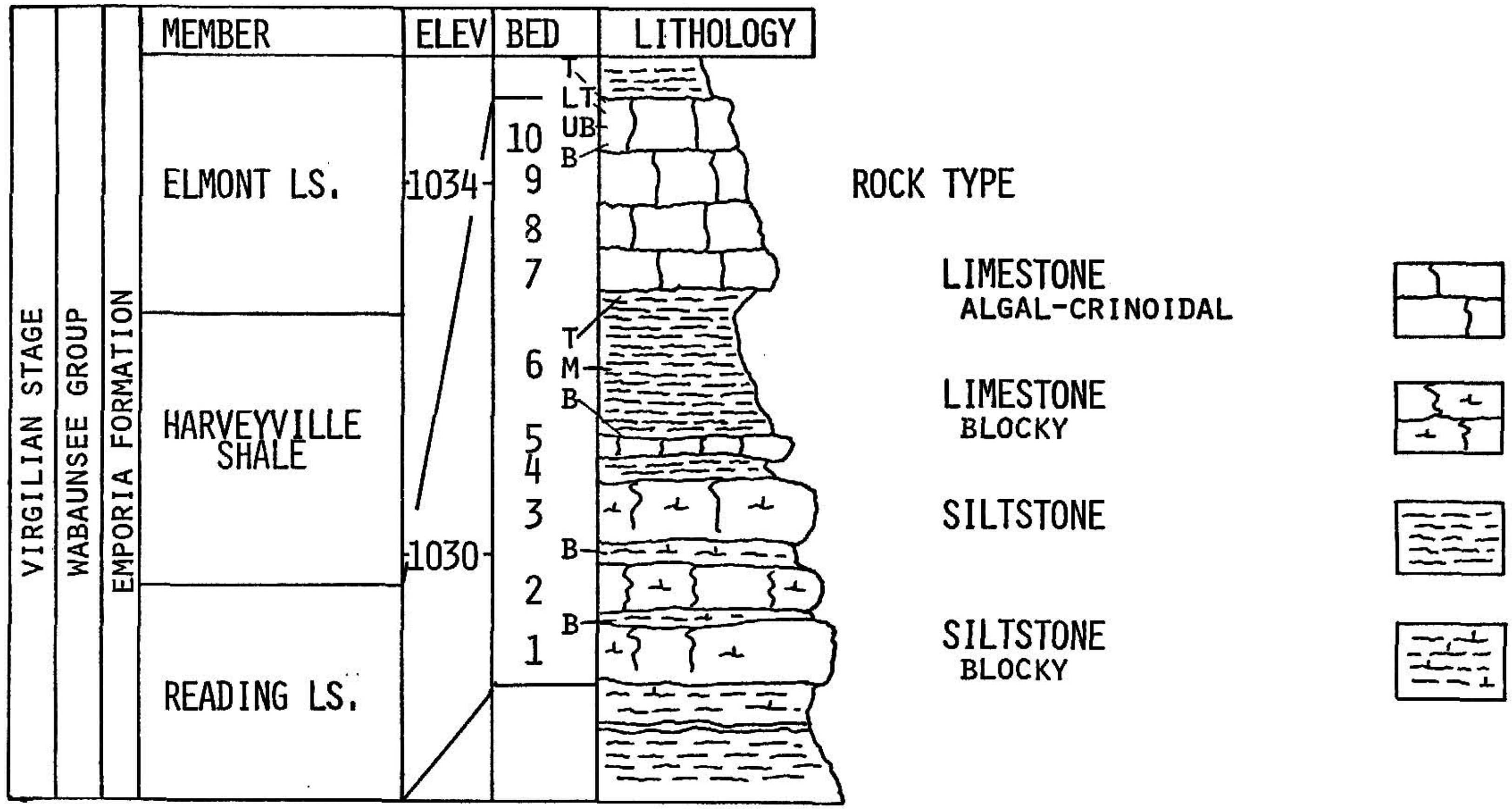


Figure 9. Lithologic Character of the Reading Limestone.

prevail in deep water or shallow protected areas. A deep water environment is contradicted by the structural setting and the biotic elements dependent on photosynthetic activity. Most significant in this category is Osagia sp. (found in beds 1-3, 7, 8, 9 and 10). Osagia sp. is a porostromatan algal growth of irregular laminated encrustations around skeletal grains. The coating consists of alternating meshes of the foraminiferid Nubecularia sp. (Hedraites sp., Henbest, 1963, p. 32) and branching threads of girvanellid algae (Johnson, 1963, p. 26). Osagia sp. has been inferred to form in agitated marine shoal water (West, 1972, per. comm.). It (and other algae) has been inferred to be a principal contributor to rock building (Johnson, 1946, p. 1108). Tasch (1957, p. 391) has suggested that marine conditions for algal growth are warm, shallow, well lighted water. Criteria for shallow water depth suggested by Hallam (1967) include, among other evidence, intense biologic activity, particularily algae or algal structures.

Carbonate Mineralogy.--Random powder x-ray diffraction analysis of the limestones of the Reading Limestone indicated that quartz and calcite are the major constituents (calcite 19 percent to 88 percent and quartz 4 percent to 31 percent). Diffraction patterns of the different units (fig. 10) show "d" spacing for quartz, calcite and dolomite. The dolomite peak has a consistent "d" spacing of 2.91 Å units while ideal dolomite has a "d" spacing of 2.88 Å units. There are two possibilities for this shift from ideal dolomite, (1) substitution of iron and/or manganese for magnesium in the dolomite-ankerite series or (2) decrease in mole percent of magnesium from a 1:1 ratio of $MgCO_3$ to $CaCO_3$ (Blatt, Middleton and Murray, 1972, p. 478). Using known proportions of magnesium carbonate and their accompanying "d" spacing values in the dolomite-ankerite series, it might be possible to estimate the amount of substitution of iron for magnesium, but because manganese can also

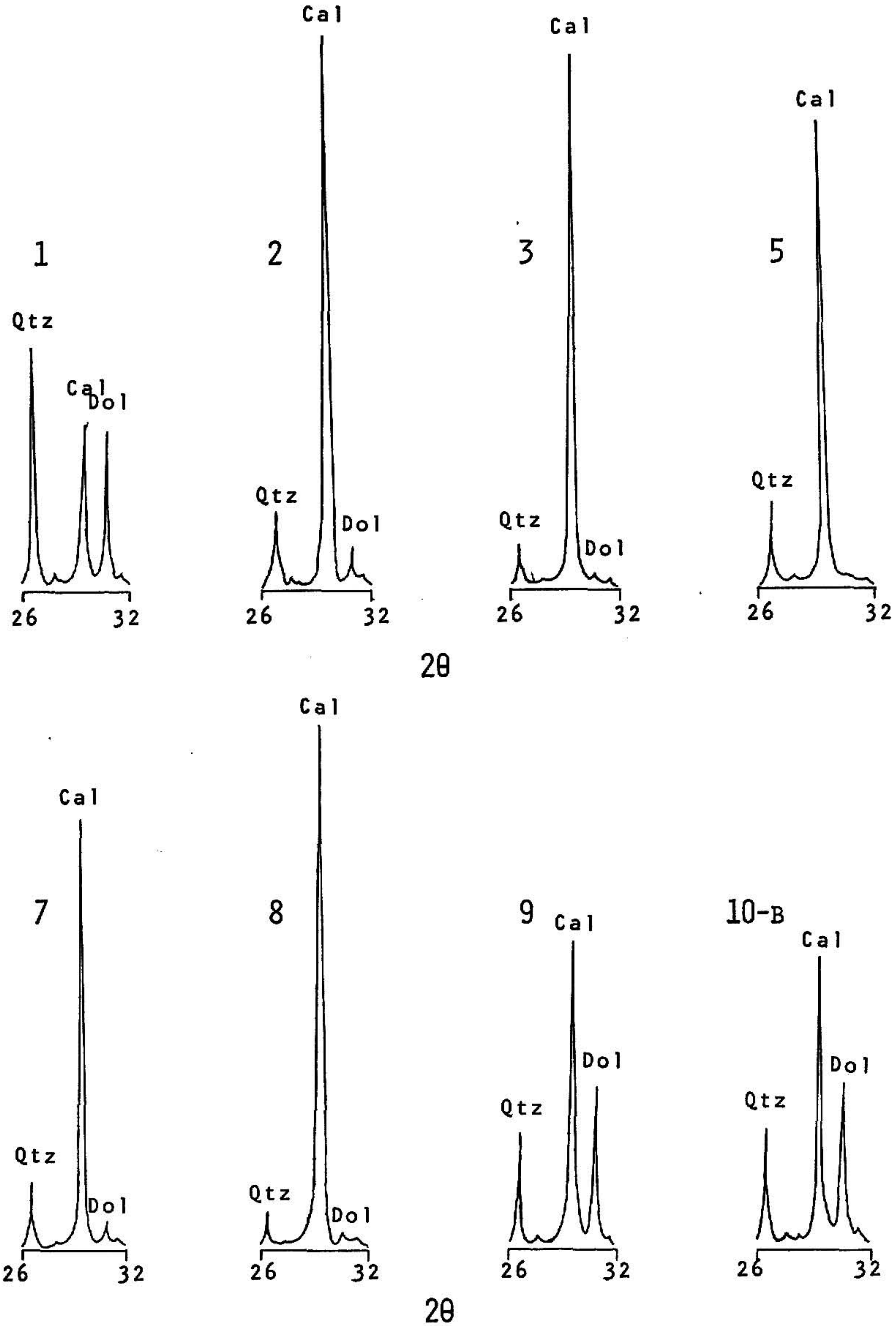


Figure 10. X-Ray Diffractograms of the Reading Limestone.

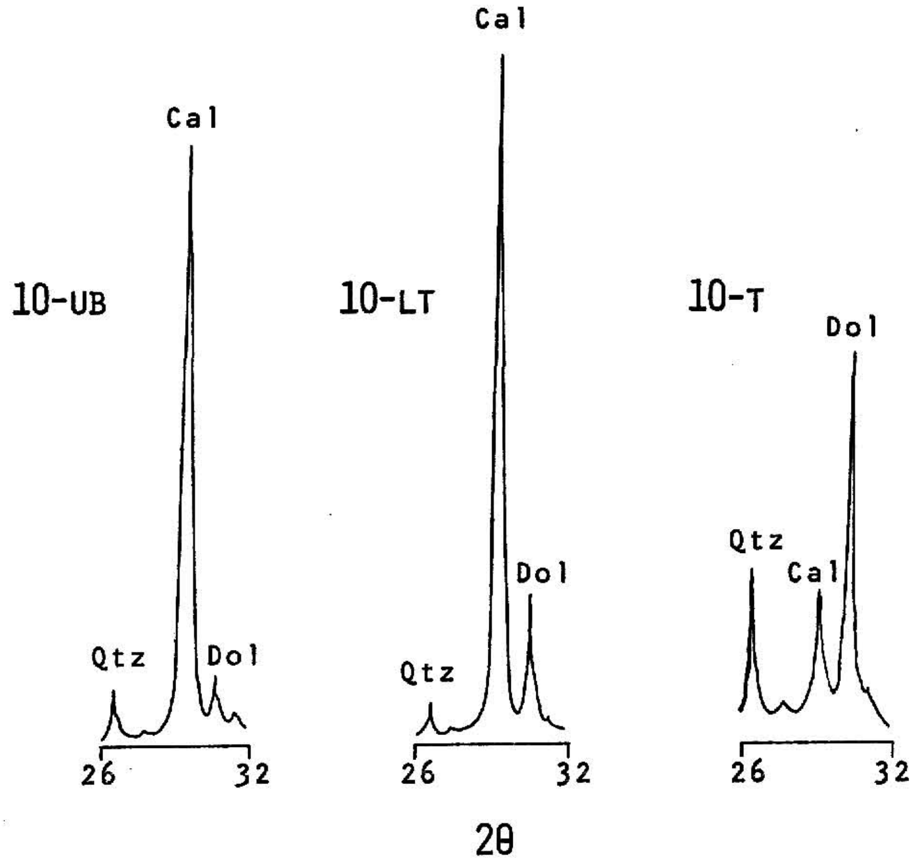


Figure 10. (continued).

substitute, substitution ratios are unknown. Spectroscopic analysis confirmed the presence of iron, manganese and magnesium. From the semi-quantitative analysis, the ratios of Fe, Mg and Mn are the same and the major substitution is iron for magnesium. If the sample contains large quantities of iron, copper radiation during x-ray diffraction will cause secondary iron flourescence, which increases the counts per second of the base line of the x-ray diffraction patterns (Mueller, 1967, p. 182). A plot of the base line cps versus the dolomite cps (fig. 11) illustrates the correlation between increases in iron fluoresence with increases in percentage of dolomite. The inference is that this dolomite is an iron rich "ferroan" dolomite.

Recent dolomite has been found in supratidal flats of the Bahamas (Shinn et al., 1965), Persian Gulf (Illing, et al., 1965) and in the Netherlands Antilles (Deffeyes, et al., 1965), therefore association of modern (primary) dolomite with supratidal flats is a reality. The mechanism of formation is linked to evaporation. On tidal flats, evaporation proceeds to the point of gypsum precipitation, which removes Ca and increases Ca/Mg ratio, effectively enriching the environment in magnesium (Adams & Rhodes, 1968). Primary dolomite is usually associated with evaporites, however magnesium enrichment may occur through biologic activity, such as algal growth. In this case dolomite is not a direct precipitate but an early diagenetic form of these magnesium rich calcites formed below the sediment-water interface (Fairbridge, 1957).

Insoluble Residues.--An estimate of the amount and characteristics of terrigenous components in a rock unit is provided by the percent and composition of insoluble residues. Mineralogical and morphological grain data permit only generalized inferences as to source areas.

Mineral identification of the sand fraction insolubles indicated that

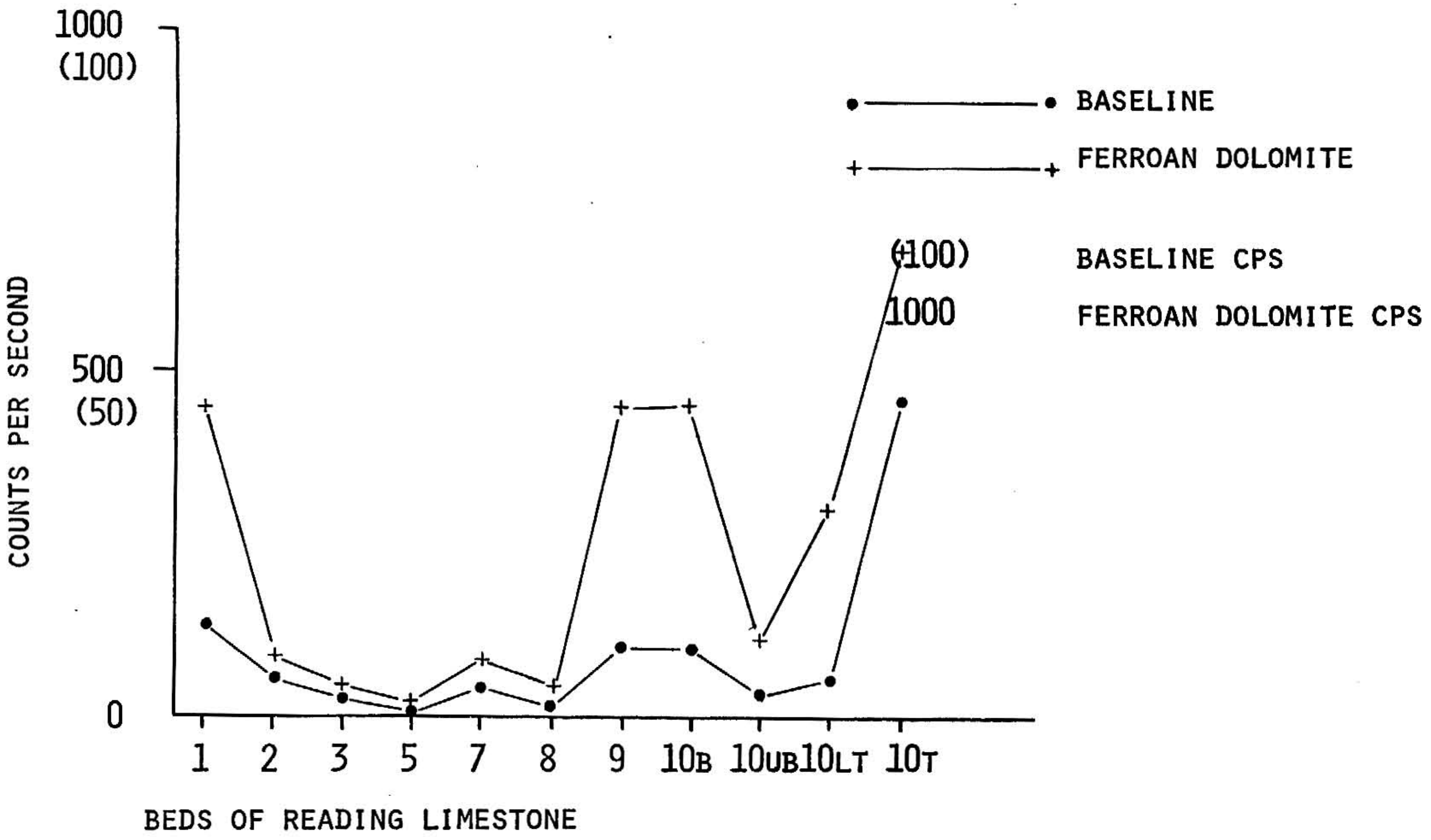


Figure 11. Diffractogram Baseline Counts Per Second Versus Ferroan Dolomite CPS.

varieties of quartz are the major components.

Common quartz exhibits a uniaxial positive sign, slight positive relief in 1.54 index oil, low birefringence, few inclusions and straight extinction. Most common inclusion type was bubble trains.

Microquartz, a sedimentary quartz type, is commonly the major constituent of chert, formed of an aggregate of pinpoint birefringent equidimensional grains, 1-5 microns in diameter ("salt and pepper" extinction). Chalcedonic quartz is another form of microquartz but differs in that it is sheaf-like, radiating thin fibres of microquartz.

Megaquartz is the term used to describe quartz derived from overgrowths, crystals, geodes, and vein filling. It is equant to elongate, grains are larger than 20 microns and usually contain abundant water filled vacuoles.

Stretched metamorphic quartz is recognized by its strong undulose extinction, crenulated borders of crystals and parallel alignment of elongate crystal units and inclusions.

Minor quantities of pyrite, limonite, celestite, feldspars and muscovite made up the remainder of sand size insolubles of the Reading Limestone. Zircon and tourmaline occur almost entirely as microlites in common quartz and microquartz.

Silt is the dominant insoluble fraction in the Reading Limestone ranging from 3.4 percent (unit 10-ub) to 72.2 percent (unit 6-m). Insoluble clay size sediment ranged from 0.2 percent (unit 10-b) to 6.2 percent (unit 6-b) and sand was usually less than 1 percent. In comparison, Krynine (1948, p. 154) said shales are mechanical mixtures of 50 percent silt, 35 percent clay and 15 percent authigenic minerals. Krumbein (1938) found that 68 percent of a Pennsylvanian marine shale in Illinois was silt. In the Reading Limestone, silt size insolubles are as high as 25.7 percent in the limestones (bed 1) and as high as 72.2 percent in the siltstones (unit 6-m), therefore its source and mode of transport are important.

Lower Limestone

Lithology.--The basal Reading Limestone consists of 2.3 feet of yellow gray to dark gray argillaceous, persistent, thin to medium wavy bedded limestone that has a blocky to subconchoidal fracture. Three limestone beds (1, 2 and 3 of fig. 9) are separated by two thin, light to dark gray, platy fossiliferous siltstone. The lower contact with the Auburn Shale is gradational, but the upper contact with the middle siltstone is sharp.

Biotic Components.--Apparent orgainsm diversity, though not as high as in the upper limestone, is much higher than the linoproductid dominated middle siltstone. In the siltstone partings are brachiopod fragments, linoproductids, crinoid debris and chonetids. Neochonetes sp., Linoproductus sp., Wilkingia cf. elliptica, Pteronites cf. peracuta, and Myalina sp. occur as whole individuals in the limestone beds. On the top surface of the upper limestone bed (3), are linoproductid pedicle valve molds. Some specimens of Wilkingia cf. elliptica and Pteronites cf. peracuta have been replaced by celestite.

Depositional Environment.--Lithologic parameters of the lower limestone are listed in Table 2. This limestone was deposited during a period of low energy possibly in a shallow lagoon or embayed shelf.

Micrite dominance infers low energy levels. Percentage of micrite in these beds (beds 1, 2 and 3) suggests that environmental energy was decreasing during deposition of the lower limestone.

Insolubles (31 percent bed 1, 19 percent bed 2 and 15 percent bed 3) indicate that input was decreasing during deposition of this limestone unit. It is also obvious that there is an inverse relationship between percentages of micrite and insolubles. An inverse relationship also exists between the

Table 2

Lithologic Parameters of the Lower Limestone of the Reading Limestone

		Unit 1	Unit 2	Unit 3
Volume Percent	Sand Size			
	Bioclasts	19.8	15.7	17.1
	Terrigenous and secondary components	4.2	0.3	2.9
	Silt Size			
	Spar	6.0	12.0	4.0
	Microspar	34.0	22.0	12.0
	Clay Size			
	Micrite	36.0	50.0	64.0
		100.0	100.0	100.0
Weight Percent	Insolubles			
	Sand size	0.7	0.5	0.4
	Silt size	25.7	14.3	11.2
	Clay size	4.8	3.9	3.7
	Solubles			
	Sand, Silt, Clay size	68.8	81.3	84.7
		100.0	100.0	100.0

percentages of calcite and those of ferroan dolomite and quartz. Of the sand fraction insolubles, common quartz and chert are the dominant terrigenous components, with some secondary quartz, limonite, celestite, muscovite and feldspar.

Petrologic study suggests that the substrate must have been a carbonate mud, with some terrigenous grains. Substrate character could have been either a packed, firm mud bottom or an unstable soupy mud bottom. However, bioturbation noted in thin section and etched vertical section (see Appendix 3) indicates reworking. As Rhodes and Young (1970) have pointed out, reworking creates an unstable substrate, sediment resuspension is increased and the sediment-water interface is less precise.

Middle Siltstone

Lithology.--Moore (1936) described the beds between the limestones of the Reading Limestone member as shale; however, the term "middle shale" is a misnomer because lithologic analysis and application of the siltstone definition of Folk (1968), indicates a siltstone.

Biotic Components.--Specimens of *Linoproductus* sp. dominate the lower bed (4) and may be preserved in life position. Occurring with these productids are *Bairdia* sp., *Cyclozoga* sp., *Derbyia* cf. *crassa* and *Spirobus* sp. Bed 5 contains whole individuals of only *Bairdia* sp. and opthalmids. Bed 6 is dominated by microfaunal elements, *Endothyra* sp., *Ammovertella* sp., *Cyclozoga* sp., *Loxonoma* sp., *Myalina* sp., *Permorphous* sp., *Bairdia* sp., *Geisina* sp., *Hollinella* sp., *Paraparchites* sp. and *Spirobus* sp. At the upper contact with bed 7, the megafaunal elements *Linoproductus* sp., *Echinaria* cf. *moorei*, *Derbyia* cf. *crassa*, *Myalina* sp., *Pteronites* cf. *peracuta*, *Wilkingia* cf. *elliptica* occur. Crinoid, echinoid and ectoproct debris occurs throughout the middle siltstone.

Depositional Environment.--Lithologic data pertinent to this unit are listed in Table 3. Middle siltstone units, in ascending order, are beds 4, 5 and 6. Bed 6 was subdivided into units 6-b (base), 6-m (middle) and 6-t (top), for insoluble residue analysis.

In the middle siltstone, insolubles are dominant with silt sized sediment dominating the residues. In the sand sized insoluble fraction, common quartz and chert are the dominant minerals. The remainder of the insoluble sand fraction is composed of lesser amounts of secondary quartz, pyrite, limonite, celestite, muscovite and feldspar. Range of insolubles percentage (57 percent in bed 4, 64 percent unit 6-b, 77 percent unit 6-m and 43 percent unit 6-t) indicates silt size sediment deposition reached a maximum in the middle of the siltstone unit (bed 6). Bed 4, though similar to bed 6, represents a brief high level of predominantly silt size sediment influx, following lower limestone deposition. Contact of bed 5 indicates cessation of this influx. Bed 5 represents a return to a carbonate depositional environment with little terrigenous input, similar to the lower limestone. Micrite dominates unit 5 (40 percent) with few insolubles (8 percent) and calcite is the major carbonate mineral (85 percent). Conditions responsible for bed 5 were terminated by deposition of terrigenous clastics (bed 6).

Terrigenous influx in bed 6 built to a maximum at 6-m (0.85 feet above the contact of beds 5 and 6), and decreased through 6-t. Detrital quartz is still the dominant mineral in the sand size insoluble residues.

There is little or no evidence of sediment reworking during middle siltstone deposition, therefore it is plausible that the substrate may have been firm. Few organisms were found in this unit and a high rate of sedimentation could have been a lethal factor to suspension feeding orgainsms (burial, clogging feeding mechanisms, burial of food, burial of young, etc.).

Table 3

Lithologic Parameters of the Middle Siltstone of the Reading Limestone

		Unit				
		4	5	6-b	6-m	6-t
Volume Percent	Sand Size					
	Bioclasts	-	10.5	-	-	-
	Terrigenous and secondary components	-	7.5	-	-	-
	Silt Size					
	Spar	-	28.0	-	-	-
	Microspar	-	14.0	-	-	-
	Clay Size					
	Micrite	-	40.0	-	-	-
			100.0			
Weight Percent	Insolubles					
	Sand size	1.0	0.6	0.5	0.5	0.7
	Silt size	51.1	6.0	57.6	72.2	36.9
	Clay size	4.7	1.2	6.2	4.4	5.7
	Solubles					
	Sand, Silt, Clay size	43.2	92.2	35.7	22.9	56.7
		100.0	100.0	100.0	100.0	100.0

Upper Limestone

Lithology.--This unit consists of four beds of dense, resistant, light to dark bluish-gray, iron stained, thick-bedded limestone that contains crinoid debris in weathered relief. Each bed (7, 8, 9 and 10 of fig. 9) has wavy subparallel contacts, averages 0.5 foot thick and is separated by less than 0.1 foot of thick, irregular, indistinct, mudstone partings. The upper contact with the overlying Harveyville Shale is sharp, even and marked by a platy, dark-gray 0.1 foot thick silty limestone. The lower contact with the middle siltstone is gradational and wavy, marked by a thin fossiliferous zone, dominated by linoproductids. Including the platy zone at the top, the upper limestone is 2.2 feet thick.

Biotic Components.--Crinoid, fusulinid and algal debris are in weathered relief. Whole individuals of Linoproductus sp., Neochonetes sp., Echinaria cf. moorei, Derbyia cf. crassa, Cyclozoga sp., Bellerphon sp., Straparollus sp., Myalina sp., Pteronites cf. peracuta, Wilkingia cf. elliptica and Enteletes cf. hemiplicatus are also present. Microfauna of this limestone include Triticites sp., Globivalvulina sp., opthalmids, ammovertellids, Bairdia sp. and Osagia sp. Disassociated elements are crinoids, echinoids and ectoprocts. Preservation is excellent with some celestite replacement of gastropods and bivalves.

The most important biotic aspect of this unit is preservation in presumed life position of the bivalves Wilkingia cf. elliptica and Pteronites cf. peracuta.

Depositional Environment.--Table 4 lists some sedimentologic parameters of the upper limestone. Bed 10 of this limestone was divided into 4 units; they are in ascending order: 10-b (bottom), 10-ub (upper base), 10-lt (lower top) and 10-t (top). Return of depositional conditions similar to those

Table 4

Lithologic Parameters of the Upper Limestone of the Reading Limestone

		Unit						
		7	8	9	10-b	10-ub	10-1t	10-t
Volume Percent	Sand Size							
	Bioclasts	7.7	15.2	22.4	15.5	19.9	8.4	28.7
	Terrigenous and secondary components	10.3	2.8	5.6	4.5	2.1	1.6	13.3
	Silt Size							
	Spar	18.0	12.0	6.0	26.0	20.0	18.0	4.0
	Microspar	32.0	10.0	6.0	40.0	24.0	28.0	42.0
	Clay Size							
	Micrite	32.0	60.0	60.0	14.0	34.0	44.0	12.0
		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Weight Percent	Insolubles							
	Sand size	1.0	0.5	0.3	0.4	1.3	0.2	0.8
	Silt size	16.5	17.1	16.4	18.0	3.4	6.3	20.7
	Clay size	1.7	1.2	1.0	0.2	0.4	0.2	3.3
	Solubles							
	Sand, Silt, Clay size	80.8	81.2	82.3	81.4	94.9	93.3	75.5
		100.0	100.0	100.0	100.0	100.0	100.0	100.0

responsible for the lower limestone and bed 5 characterize the upper limestone. The environment was one of low energy, carbonate deposition with less terrigenous influx than during deposition of the lower limestone.

Insolubles are consistently low until unit 10-t where they increase (25 percent). Of the size fractions, silt dominates the insolubles. In the sand fraction, detrital quartz (common quartz and chert) is the major component with the remainder of the sand fraction made up of minor amounts of muscovite, feldspar, secondary quartz, pyrite, limonite and celestite.

Micrite is dominant in beds 7, 8 and 9 but microspar dominates units 10-t and 10-b (42 percent and 40 percent) producing a biomicrosparite.

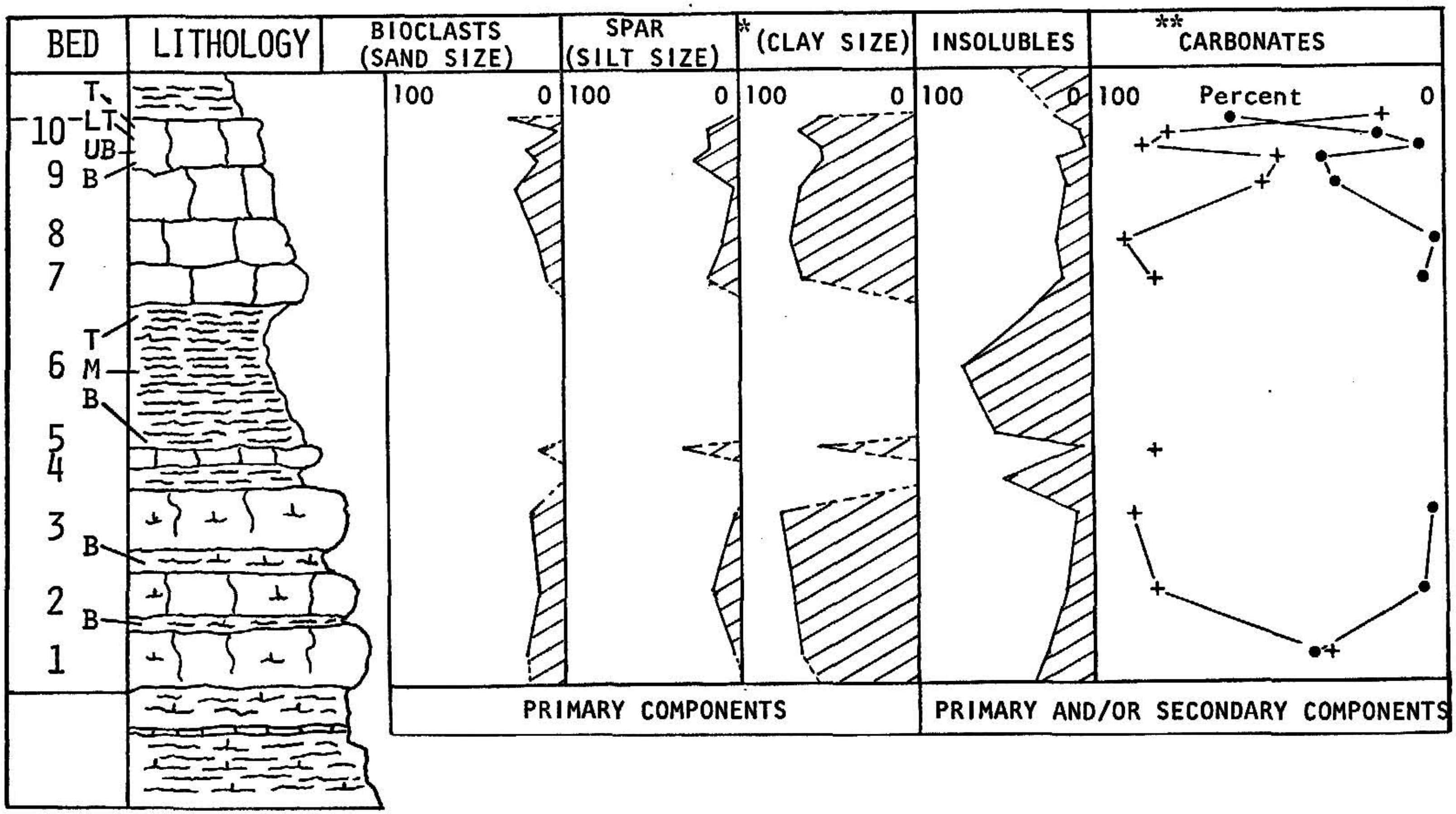
Carbonate deposition was more consistent in the upper limestone. The lower limestone contains two siltstone beds (base of beds 2 and 3) whereas none occur in the upper limestone. Calcite is dominant in all beds except where ferroan dolomite dominates (59 percent in unit 10-t). Increase and variability of insolubles in bed 10, and changes in carbonate type and mineralogy suggest a change from carbonate deposition of the upper Reading Limestone to terrigenous deposition represented by the Harveyville Shale. Contact between the Harveyville Shale and unit 10-t indicates the end of conditions responsible for the upper limestone.

Substrate stability or instability during upper limestone time was probably more important for organism survival than rates of sedimentation. Evidence of bioturbation is again abundant throughout this interval and indicates an unstable substrate. However, bioturbation decreases and insolubles increase in bed 10. Therefore sedimentation rate during deposition of bed 10 was possibly the important factor governing survival of benthic organisms. Reducing conditions below the sediment-water interface would increase as bioturbation decreased and rates of sedimentation increased. This is supported by pyrite which makes up 16 percent of the sand size insolubles in unit 10-t as compared to 8 percent (next highest) in unit 6-b. Thin section analysis also supports this as 11 percent of unit 10-t was pyrite compared to 0.5 percent in bed 3.

Summary

Summarizing environmental conditions during Reading Limestone deposition, it may be inferred from the tectonic setting that the study area was shallow lagoon or embayed shelf. Interpretations about grain size and mineralogy of the primary components of the Reading Limestone (fig. 12) suggests that the upper and lower limestones were dominantly clay size micrite and microspar (microspar, being an aggraded micrite, would have originally been clay size). On the other hand, the middle siltstone is dominantly silt size sediment. With such fine grained sediments as primary components, the inference is that this was a low energy environment.

Figure 12 also shows the presence of significant amounts of ferroan dolomite. This dolomite could be an authigenic component or a primary component. There is insufficient evidence in thin section analysis to suggest an authigenic origin. If ferroan dolomite was a primary component, it may have formed in place. However, this seems unlikely as little evidence indicates that this would be a tidal flat (lack of evaporites, laminated algal stromatolites, dessication cracks, ripple marks, etc.). The third hypothesis and the preferred hypothesis is that the ferroan dolomite was detrital. An explanation for not noting detrital dolomite in thin section is that the ferroan dolomite is probably found most commonly in the silt fraction (-230 fraction was used for random powder x-ray analysis). A truly representative amount of silt size sediment could not be noted in a 20x30 mm area of thin



*MICRITE AND MICROSPAR

**CALCITE -+—+
FERROAN DOLOMITE -●—●

Figure 12. Some Inferred Primary and Secondary Lithologic Components of the Reading Limestone.

section in which micrite and microspar dominate. If it may be suggested that the ferroan dolomite has a terrigenous origin, where did the dolomite come from?

A possible origin of ferroan dolomite in the Reading Limestone may be that dolomite formed in tidal flats, was transported to the site, deposited as detrital dolomite and postdepositionally altered. Reducing conditions could have existed below the sediment-water interface and in this environment some Mg ions are replaced by ferrous ions. Goldsmith and Graf (1958), found that dolomites of 1:1 ratios of $CaCO_3$ and $MgCO_3$ had a 2.88 Å "d" spacing and were found most commonly with evaporites. Additionally they infer that expanded structure of dolomite is apparently related to postdepositional origin. Sabins (1962) investigated Cretaceous strata and showed that detrital dolomite exists in sedimentary rocks. Field reconnissance in the vicinity of Onaga, Kansas, indicates that contemporary tidal flats may have existed. Renfro (1962) in his thesis on the Elmont Limestone of the Emporia Formation, found gravel size intraclasts of dolomite.

Finally, the dominance of silt size sediment in the insolubles of the Reading Limestone, particularily the middle siltstone and the negative association between insoluble silt percent and micrite percent (fig. 12), suggests that silt input or deposition in a low energy carbonate environment, was the major factor in depositional environmental change. If this is true, where did the silt come from?

Claystones and shales are composed of (1) products of abrasion (mainly silt), (2) end products of weathering (usually clays) and (3) chemical-biochemical additions. Composition and amount of mechanically derived silt are dependent upon relief and climate of the source area. If silt is not available, then sediments are enriched with clay and other constituents (Pettijohn, 1957, p. 357). Abundant silt in the Reading Limestone insolubles indicates that a source area or areas of silt sized particles was available during Reading Limestone deposition and that a transporting agent was available. Johnson and Adkison (1967, p. 80) suggested that uplands existed east and south of a large drainage system off the Canadian Shield and probably contributed some sediment.

Air and water are two major media of sediment transport. Pennsylvanian and some Permian rock sequences in the mid-continent are explained by cyclic sedimentation in an aqueous medium. Udden (1912) recognized cyclicity of beds, Weller (1930) developed the concept and Wanless (1932) and Moore (1931) refined this concept. The dominant agent of transportation is assumed to be water and aeolian transport has been more or less ignored. Aeolian transported silt and clay size sediment in upper Pennsylvanian strata may be significant. Twenhofel (1961, p. 65) cited aeolian deposits of great areal extent and thickness as evidence that the atmosphere is capable of transporting great amounts of sediment. Clay mineral suites in bottom sediments off Australia, in the North Atlantic, in the North Pacific and off the south coast of Africa, have been attributed to concentrations by jet stream and prevailing wind transport (Blatt, Middleton & Murray, 1972, p. 381). Further, the availability of sediment for transportation by wind from continental sources was better, until the appearance of extensive plant cover between Cretaceous and Miocene times (Schumm, 1968, p. 1571). Hattin (1962) suggested that silt in the Fairport shale of western Kansas was wind derived. Arid conditions seem to be optimum for wind transportation of sediments. The Pennsylvanian and Permian sequence in Kansas seems to indicate the development of arid conditions, specifically more and thicker units of red shales and evaporites upward. To infer that sand, silt and clay fractions of the Reading Limestone were transported by wind is premature, but to suggest that they were transported solely by water may be a narrow view point. Geometry of shales (thin, persistent, large areal extent) with sharp upper and lower contacts, resemble closely the geometry of known wind deposited sediments (i.e. Tertiary volcanic ash of Kansas, Oklahoma and Nebraska). High carbonate content of the Reading Limestone siltstones suggests terrigenous deposition in a carbonate environment.

BENTHIC MARINE COMMUNITIES

General Statement

Reconstruction of a fossil community implies the intent to study interrelations of fossil species with their environment, specifically paleosynecology. To accomplish this requires data on fossil species and the environment. A fossil community as defined by Fagerstrom (1964) is a fossil assemblage in which nearly all specimens belong to the same ecological community and are present in about the same sizes and numbers as when they were alive. Fossil communities have undergone a minimum of preburial alteration and most are in their original habitats and life positions. If a fossil community has undergone moderate preburial alteration, according to Fagerstrom (1964) it is a residual fossil community. A residual fossil community is a fossil assemblage in which nearly all specimens belong to the ecological community but are not in the same numbers and sizes as when they were alive.

Selection of taxonomic entities of the communities was based on data which suggested the fossil individuals of species died where they lived and suffered little post-mortem change. Selection was also a function of sedimentologic data, from which physical conditions (energy levels, substrate type, water depth, sedimentation rates, mineralogy, etc.) could be inferred. Size frequency distributions, position with respect to enclosing lithology, preservation, dispersion of fossils, density, composition and diversity were other criteria used. Articulation percent, valve ratios and degree of fragmentation, though common to such studies, were rarely used because of the small number of whole specimens available.

Size frequency distribution may be particularly useful in recognizing alterations of species populations. Variation of these distributions may be a function of post-mortem effects (i.e. scavenging, transport, solution, sample bias, etc.) or pre-mortem effects (i.e. selective predation, recruitment failure, transportation, etc.). Craig (1967) pointed out, transportation tends to remove smaller individuals and produce a normal "bell" shaped curve. However, this appears to have been insignificant in the Reading Limestone because of the abundance of small forms among different taxa. Post-mortem solution after burial is probably minimal in fine grained sediments because, solution effects are restricted by low permeability of the matrix (Craig and Hallam, 1963). Sampling bias was minimized by careful collecting.

Studies by Olson (1957) showed that invertebrate species are generally characterized by positive skewed size frequency distribution. Studies on distributions of modern marine invertebrates (Percival, 1944; Rowell, 1960; Rickwood, 1968) support Olson's conclusions. This positive (right skewed) distribution has been used as one of many criteria by Boucot (1953), Veevers (1959), Fagerstrom (1964) and West (1970) to recognize components of fossil communities.

Within the community, individuals of each species possess a unique set of ecological responses. Precise definition of these responses is not feasible, but the structure of the community may be inferred through association of species and recognition that these species occupy different energy transfer categories (i.e. feeding type, mode of life and level of competition) within the ecosystem.

Throughout this study, ecosystem categories of species will be in terms of (1) feeding type, (2) mode of life, (3) level of competition (i.e. producer primary consumer, secondary consumer, etc.) and (4) trophic group. West (1970) defined four feeding types; (1) those feeding on particulate matter, (2) suspension feeders, (3) deposit feeders and (4) predators. The diet of particulate feeders consists of spores, pollen, algae, invertebrate larvae or nutrients, however in this study (as in West, 1970), particulate matter refers almost exclusively to complex organic molecules. Suspension feeders, which include ectoprocts, brachiopods, some bivalves and crinoids, feed primarily on suspended organic matter. The distinction between "suspended" and "particulate" matter is that particulate matter may be suspended matter or detrital bottom material. Deposit feeders for this investigation, include gastropods, ostracodes, trilobites and echinoids, which feed on bottom detritus. Predators, while difficult to distinguish from scavengers, when dealing with invertebrates, are represented by echinoids and fish.

Modes of life are (1) epifaunal (living on substrate) and (2) infaunal (living within substrate). Rudwick (1970) the mode of life of productids should be termed quasi-infaunal. This term means that an epifaunal organism simulates an infaunal mode of life by being partly buried. Semi-infaunal mode of life means that an organism is half below and half above the substrate.

Levels of competition refer to the food chain and are as defined by Beerbower (1968, p. 117), (1) producers (plants, level at which complex organic molecules are made from simpler inorganic molecules), (2) primary consumers (herbivores). (3) secondary consumers (carnivores) and (4) tertiary consumer (larger carnivore). Assignment of species to a particular level is based on feeding type, relative size and associations of organisms (Beerbower, 1968, p. 119).

These categories of competition do not adequately portray what happens in a marine system. Odum (1959) pointed out that marine organisms most likely to reside at the primary consumer level are those feeding types that subsist on phytoplankton suspended in the water and deposited on the bottom. Three of the four basic feeding types just outlined, particulate, suspension and deposit feeders fall into this category.

Energy transfer through modern benthic food chains appears to indicate that short simple food chains existed and that most benthic species are and were primary consumers. Competition for the same resource (producers) should eliminate all but one or two species (competitive exclusion principle) at the primary consumer level, however species diversity indicates that this is not true. Petersen (1913) suggested in his studies on benthic communities of the North Sea, that relatively little interdependance exists amoung consumers in soft bottom communities. Most benthic community members, exist together because they happen to prefer similar environmental conditions.

A more precise definition of resources used by primary consumers has been proposed by Turpaeva (1957). She studied the interaction of benthic community members through competition and noted shortened food chains, as did Petersen. But unlike Petersen, she found that when trophic levels are defined according to <u>food resources used</u>, trophic structural patterns and species interdependence is pronounced. The marine benthic habitat offers favorable opportunities for feeding by only a few methods and in communities, each method or <u>trophic group</u> is dominated by one species satisfying the principle of competitive exclusion. Walker (1972, p. 83) summarized Turpaeva's trophic groups and related them to terminology used in the United States. Four trophic groups as modified by Walker used in this study are: (1) infaunal deposit feeders (feed within bottom sediment), (2) epifaunal deposit feeders (collect detritus from sediment surface), (3) low level suspension feeders (filter food from water immediately above the bottom; can be infaunal or epifaunal suspension) and (4) high level suspension feeders (filter food from water some distance above the bottom). Turpaeva had a fifth trophic group called "awaiters" for those organisms dependent upon water circulation for their resources. Awaiters refers to a mode of gathering food instead of the zone of resources and for purposes of this study "awaiters" (i.e. crinoids, ectoprocts) will be considered high level suspension feeders.

Trophic Group Assignment

Table 5 classifies Reading Limestone taxa on the basis of feeding type, mode of life, level of competition and trophic group. Assignment of Reading Limestone species to trophic groups was accomplished by using data from West (1970) and Pearce (1973) on inferred feeding types.

Foraminiferids are those organisms that feed largely on particulate organic matter, which may be taken from suspension in the water mass or on the sea bottom (West, 1970, p. 83). They are inferred to have an epifaunal mode of life (West, 1970, p. 100) and are classed as epifaunal deposit feeders.

West (1970) classed ectoprocts as epifaunal deposit feeders. I class them as high level suspension feeders on the basis of feeding type and shell morphology.

Brachiopods are also classed as suspension feeders (West, 1970, p. 83). Functional morphology suggests that they probably belonged to the low level suspension feeders. Most brachiopods were epifaunal, except for the quasi-infaunal Echinaria cf. moorei (Pearce, 1973) and Linoproductus sp. (Grant, 1963).

Table 5

Feeding type, Mode of Life, Level of Competition and Trophic Group of Taxa in the Reading Limestone

Taxa	Feeding Type	Mode of Life	Level of Competition	Trophic Group
Triticites sp.	Particulate	Epifaunal	Pri. Cons.	Epi Dep
Globivalvulina sp.	Particulate	Epifaunal	Pri. Cons.	Epi Dep
Opthalmid	Particulate	Epifaunal	Pri. Cons.	Epi Dep
Endothyra sp.	Particulate	Epifaunal	Pri. Cons.	Epi Dep
Ammovertella sp.	Particulate	Epifaunal	Pri. Cons.	Epi Dep
Ectoproct	Suspension	Epifaunal	Pri. Cons.	High Sus
Neochonetes sp.	Suspension	Epifaunal	Pri. Cons.	Low Sus
Linoproductus sp.	Suspension	Quasi-Inf	Pri. Cons.	Low Sus
Enteletes cf. hemiplicatus	Sus.	Epifaunal	Pri. Cons.	Low Sus
Echinaria cf. moorei	Suspension	Quasi-Inf	Pri. Cons.	Low Sus
Derbyia cf. crassa	Suspension	Epifaunal	Pri. Cons.	Low Sus
Neospirifer sp.	Suspension	Epifaunal	Pri. Cons.	Low Sus
Cyclozoga sp.	Deposit/Scav	Epifaunal	Pri. Cons.	Epi Dep
Loxonoma sp.	Deposit/Scav	Epifaunal	Pri. Cons.	Epi Dep
Bellerphon sp.	Deposit/Scav	Epifaunal	Pri. Cons.	Epi Dep
Straparollus sp.	Deposit/Scav	Epifaunal	Pri. Cons.	Epi Dep
Wilkingia cf. elliptica	Suspension	Semi-Inf	Pri. Cons.	Low Sus
Pteronites cf. peracuta	Suspension	Semi-Inf	Pri. Cons.	Low Sus
Myalina sp.	Suspension	Epifaunal	Pri. Cons.	Low Sus
Permorphous sp.	Suspension	Epifaunal	Pri. Cons.	Low Sus
Aviculopecten sp.	Suspension	Epifaunal	Pri. Cons.	Low Sus
Ditymopyge sp.	Deposit	Epi-Inf	Pri. Cons.	Epi Dep
Bairdia sp.	Deposit	Nektonic-Inf	Pri. Cons.	Epi Dep
Geisina sp.	Deposit	Nektonic-Inf	Pri. Cons.	Epi Dep
Hollinella sp.	Deposit	Nektonic-Inf	Pri. Cons.	Epi Dep
Parapachites sp.	Deposit	Nektonic-Inf	Pri. Cons.	Epi Dep
Cavellina sp.	Deposit	Nektonic-Inf	Pri. Cons.	Epi Dep
Crinoid	Suspension	Epifaunal	Pri. Cons.	High Sus
Echinoid	Predator	Epifaunal	Sec. Cons.	-
Fish debris	Predator	Nektonic	Ter. Cons.	-
Osagia sp.	-	-	Producer	-
Spirobus sp.	Suspension	Epifaunal	Pri. Cons.	Low Sus

Gastropods are listed as deposit feeders/scavengers by West (1970, p. 83). Deposit feeders/scavengers may be epifaunal or infaunal, but are assigned to the epifaunal deposit feeders because West (1970, p. 100-101) infers that these were epifaunal organisms (i.e. Straparollus sp., Bellerphon sp. and pseudozygopleurids).

Bivalves in this study are interpeted as being suspension feeders (West, 1970, p. 83, 100 and Pearce, 1973, p. 21), therefore were assigned to the low level suspension trophic group. Basis for assignment to this category was that these organisms appear to have had a mode of life associated with life on or in the substrate (epifaunal or semi-infaunal). Some pectinoids were capable of a nektonic existence but all pectinoids in the Reading Limestone possess morphological features which support a bysally attached (epifaunal) habit. Semi-infaunal bivalves Wilkingia cf. elliptica and Pteronites cf. peracuta may have protruded far enough above the sediment-water interface that they would have been classified (according to Turpaeva) as Filter-B (high level suspension) trophic group. Pearce (1973, p. 21), infers that these bivalves (also the brachiopod Linoproductus sp.) all belong to the Filter-B (high level suspension) trophic group. There is no real evidence indicative of a specific boundary (in millimeters above the substrate) between high and low level trophic groups within these fossil benthic communities. If these organisms were confined solely to the high level group, they would be in direct competition with crinoids and ectoprocts for resources. Absolute abundance of crinoids and ectoprocts is almost impossible to determine, however visual estimation in the field and in etched vertical sections indicates that where productids and bivalves flourished (middle siltstone and upper limestone) crinoids and ectoprocts also flourished.

Trilobites and ostracodes constitute the Reading Limestone arthropods.

Trilobites, specifically Ditymopyge sp. is believed to be a deposit feeder (West, 1970, p. 100). Walker (1972, p. 87) classed it as an epifaunal deposit feeder. Ostracodes are deposit feeders and are nektonic to infaunal in their mode of life (West, 1970, p. 83) and I have classed them as epifaunal deposit feeders.

Crinoids are inferred to be epifaunal suspension feeders (West, 1970, p. 100) and functional morphology suggests that they belong to the high level suspension trophic group. Echinoids and fish are predators (West, 1970, p. 84) therefore are secondary consumers and not included in the trophic grouping because trophic assignment in this study is limited to primary consumers. Osagia sp. probably represents the producer level, but for the same reasons is not included in the trophic grouping.

Spirobus sp. is classified as an epifaunal suspension feeder (West, 1973, per. comm.) therefore would probably belong to the low level suspension trophic group.

Reading Limestone Communities

Stratigraphically three marine benthic communities can be recognized in the Reading Limestone Member of the Emporia Limestone. These are in ascending order, (1) the Neochonetes Community, dominating the lower limestone, (2) the Linoproductus Community, dominant during middle siltstone deposition and (3) the Wilkingia-Pteronites Community dominating the period of upper limestone deposition (fig. 13).

Neochonetes Community

Stratigraphically, the Neochonetes Community is the lowest of the three communities and was found in the lower limestone of the Reading Limestone. Specifically the assemblages studied occurred in the siltstone breaks at the

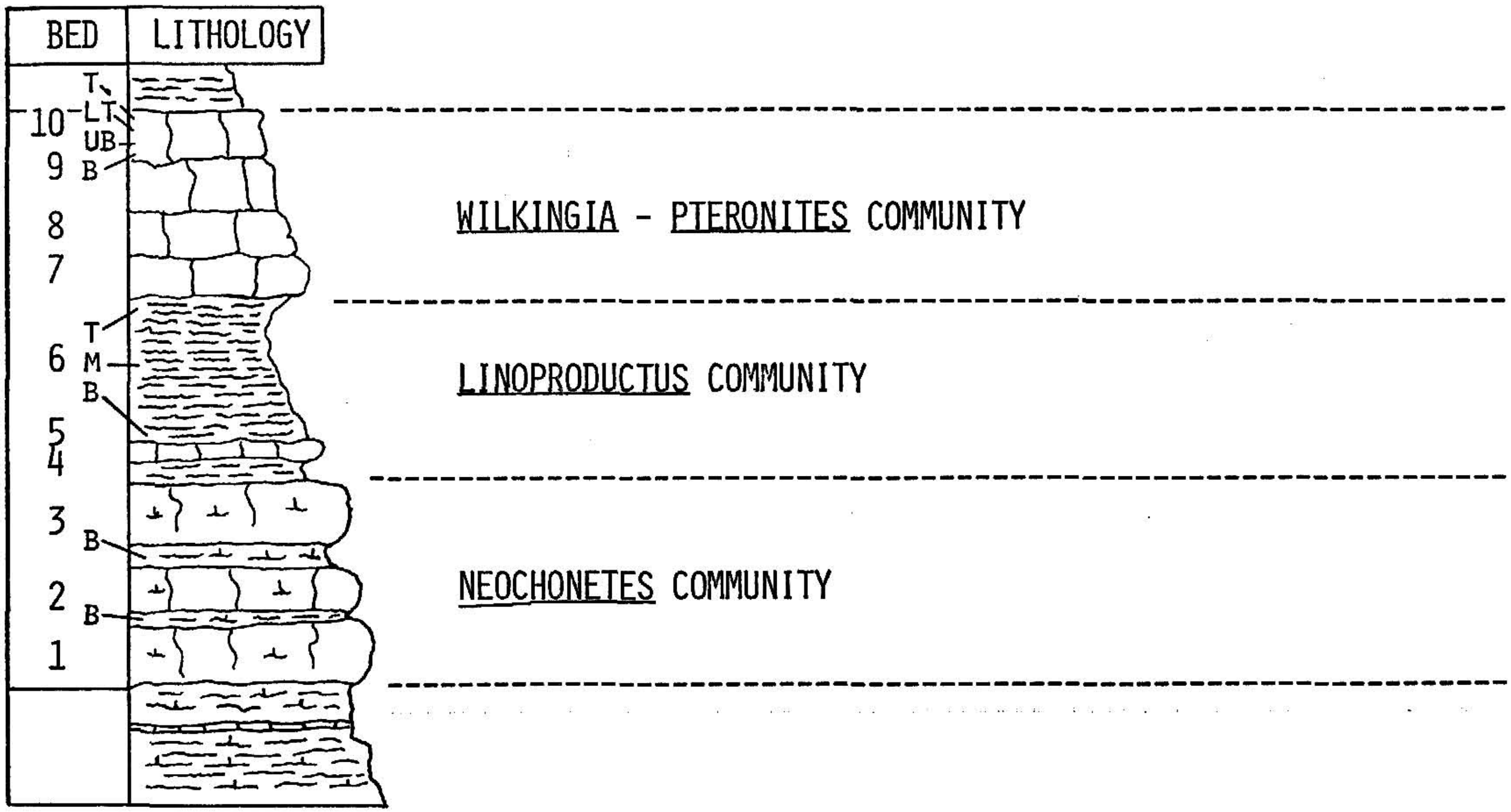


Figure 13. Stratigraphic Occurence of Reading Limestone Communities.

base of beds 2 and 3. This community, represented by 18 species, probably lived on the bottom of a shallow lagoon and/or embayed shelf during a period of shallow, low energy, carbonate deposition. Substrate was dominately carbonate mud, with moderate bioturbation and moderate amounts of terrigenous detritus.

Biotic Elements.--Composition of the Neochonetes Community is indicated in Table 6. Dominating the community is the brachiopod Neochonetes sp. Other megafossils are the brachiopods Linoproductus sp., Neospirifer sp., Derbyia cf. crassa and the bivalves Myalina sp., Pteronites cf. peracuta and Wilkingia cf. elliptica. The most abundant microfossil is the ostracode Bairdia sp. Other microfossils are Permorphous sp. (bivalve) and the foraminiferids Globivalvulina sp., Endothyra sp. and opthalmids. Fragmented and/or disassociated skeletons considered part of the community are ectoprocts, crinoids, echinoids and trilobites.

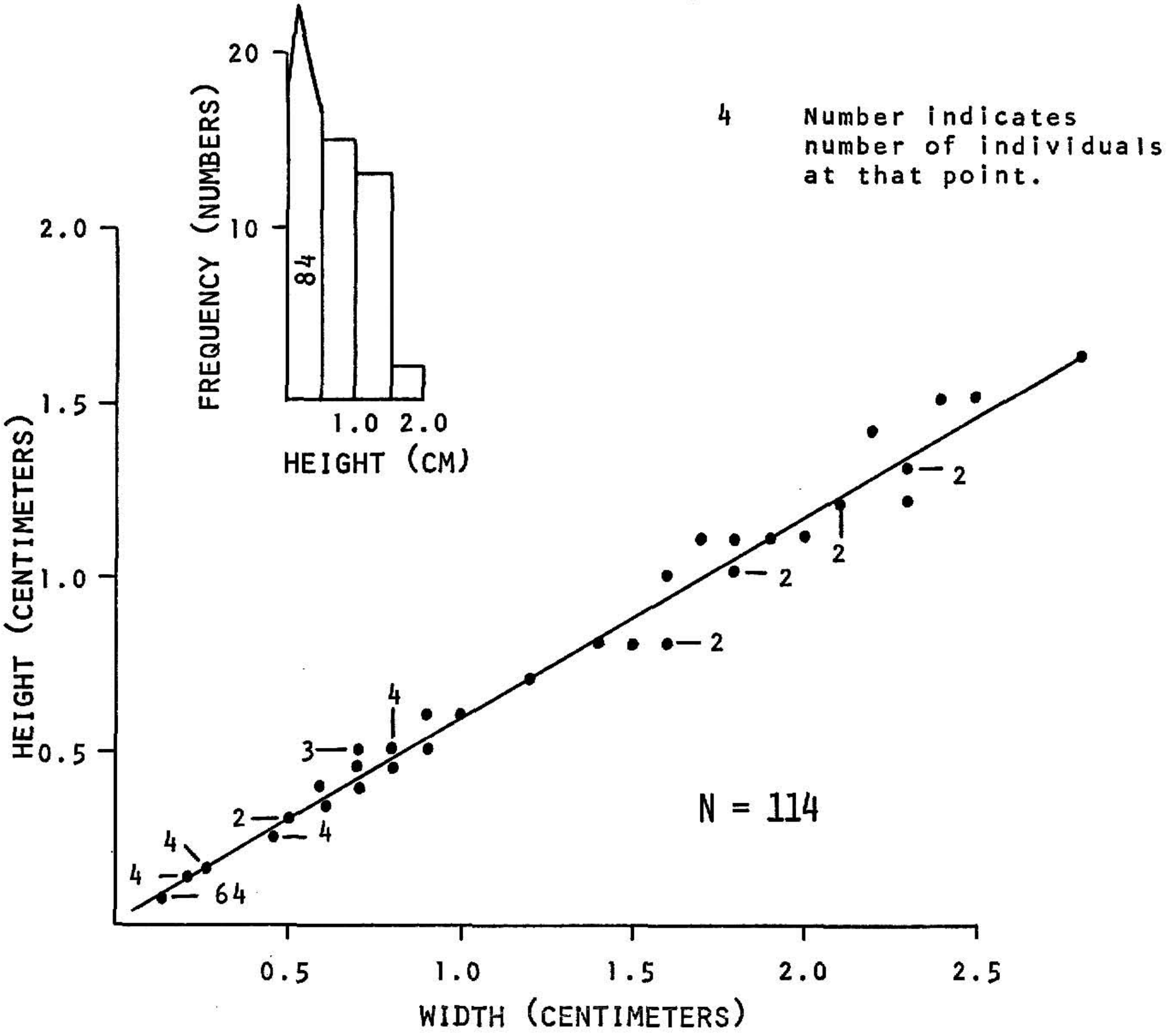
Size frequency distributions for Neochonetes sp. were constructed (figs. 14 and 15). The frequency distribution of Neochonetes sp. in unit 3-b is negatively skewed (fig. 15) while the frequency distribution of Neochonetes sp. in unit 2-b is positively skewed (fig. 14). A positive skewed distribution probably represents part of a fossil community while a negative skewed distribution implies "non-normality" of a fossil community. However, some assurance exists that these two chonetid assemblages are from the same population. Comparison of reduced major axis of figures 14 and 15, indicates that significant differences do not exist between the two chonetid samples (Table 7). Therefore if these two assemblages are of the same population, some factor must be altering curve shape in unit 3-b. Curve shape is a result of rates of mortality and natality, a possible change in either could result in a negative skewed distribution. Craig and Oertel (1966, p. 333) using living and fossil

Table 6

Composition of the Neochonetes Community

Taxonomic Entity	No. of Indiv.	Level of Comp.	Feeding Type	Mode of Life	Trophic Group
Globivalvulina sp.	6	Primary	Part.	Epi.	Epi Dep
Opthalmid	16	Primary	Part.	Epi.	Epi Dep
Endothyra sp.	5	Primary	Part.	Epi.	Epi Dep
Ammovertella sp.	9	Primary	Part.	Epi.	Epi Dep
Ectoproct* Ramose	98	Primary	Sus.	Epi.	High Sus
Neochonetes sp.	144	Primary	Sus.	Epi.	Low sus
Linoproductus sp.	2	Primary	Sus.	Quasi-Inf	Low Sus
Derbyia cf. crassa	1	Primary	Sus.	Epi.	Low Sus
Loxonoma sp.	1	Primary	Dep/Scav	Epi.	Epi Dep
Wilkingia cf. elliptica	1	Primary	Sus.	Semi-Inf	Low Sus
Pteronites cf. peracuta	3	Primary	Sus.	Semi-Inf	Low Sus
Myalina sp.	1	Primary	Sus.	Epi.	Low Sus
Permorphous sp.	64	Primary	Sus.	Epi.	Low Sus
Ditymopyge sp.*	4	Primary	Dep.	Epi-Inf	Epi Dep
Bairdia sp.	1864	Primary	Dep.	Nek-Inf	Epi Dep
Crinoid*	608	Primary	Sus.	Epi.	High Sus
Echinoid*	521	Secondary	Pred.	Epi.	-
Osagia sp.	31	Producer	-	-	-

*Fragments of individuals.



REDUCED MAJOR AXIS

$$Y = .0177 + .5696X$$

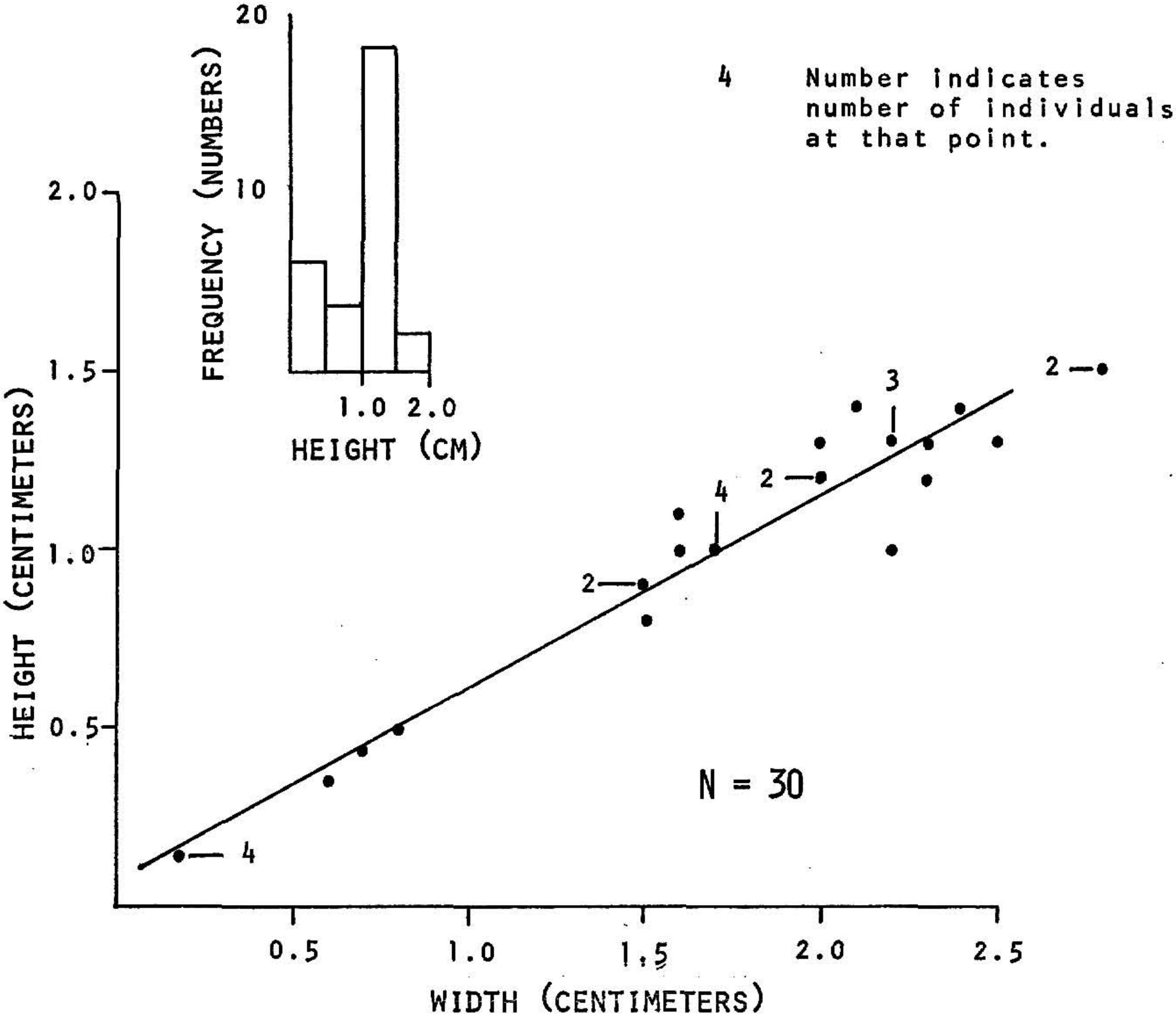
STANDARD ERROR OF SLOPE

.000198

CORRELATION

+0.990

Figure 14. Neochonetes Size-Frequency Characteristics: Bed 2.



REDUCED MAJOR AXIS

$Y = .0711 + .5395X$

STANDARD ERROR OF SLOPE

.00386

CORRELATION

+0.979

Figure 15. Neochonetes Size-Frequency Characteristics: Bed 3.

Table 7

Comparison of Reduced Major Axis (*Neochonetes* sp. Height-Width) Between Samples from Bed 2 and Bed 3

Slope Comparison	$Z = \dfrac{k_1 - k_2}{\sqrt{s_{k_1}^2 + s_{k_2}^2}}$
Variables	Slope = k
	Standard Error of the Slopes = $s_{k_i}^2$
Comparison	Z = 1.39

Probability that Z will be exceeded in two samples from the same population equals (=) .1646.

Conslusion: There is no significant difference between the slopes implying that the samples came from the same population.

populations, showed that in invertebrate populations where recruitment is constant, and mortality increasing, the size frequency distribution is negatively skewed. A possible reason for increasing mortality is changing substrates which introduced environmental parameters unsuitable for the chonetid population. Studies by Johnson (1964, p. 118), observed that fluctuations in density of individuals appears to be associated with physical rather than biological changes in the environment.

Community Structure.--Competition for resources in this community is concentrated in the primary consumer level as 16 of 18 species are primary consumers (Table 8). Details of community structure appear when it is defined in terms of trophic groups (fig. 16). The community is dominated by suspension feeders and Neochonetes sp. is the dominant species. Dominance of a particular species in the remaining trophic groups is difficult to establish because individuals are disassociated and/or fragmented. Trophic level flexibility of ostracodes, trilobites and foraminiferids may have been an adaptation to avoid direct competition with other species. It is likely that they used more than one food resource.

Predators at the secondary consumer position are low in numbers of species. Producers are also scarce but this is probably because they lack preservable parts.

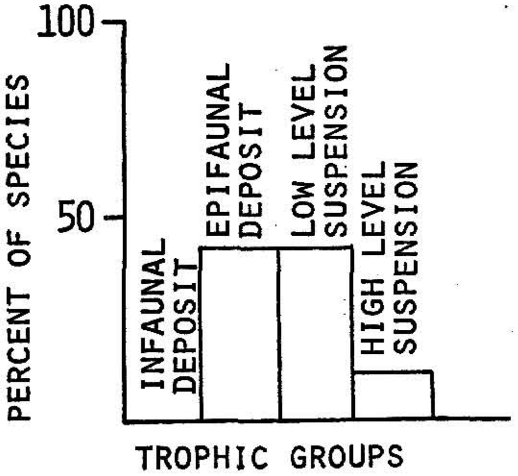
Linoproductus Community

The Linoproductus Community occurs stratigraphically, in the middle siltstone and specifically was found at the upper contact of bed 6 and lower contact of bed 4. There are only 13 species in this community, the lowest number of all communities in the Reading Limestone. The depositional environment in which the Linoproductus Community thrived was probably similar in

Table 8

Number of Species According to Feeding Type, Mode of life and Level of Competition in the *Neochonetes* Community

Subject	Divisions	Number
Feeding Type	Particulate	4
	Suspension	9
	Deposit	3
	Predator	1
Mode of Life	Epifaunal	14
	Quasi-Infaunal	
	Semi-Infaunal	1
	Infaunal	-
Level of Competition	Producer	1
	Primary Consumer	16
	Secondary Consumer	1
	Tertiary Consumer	-



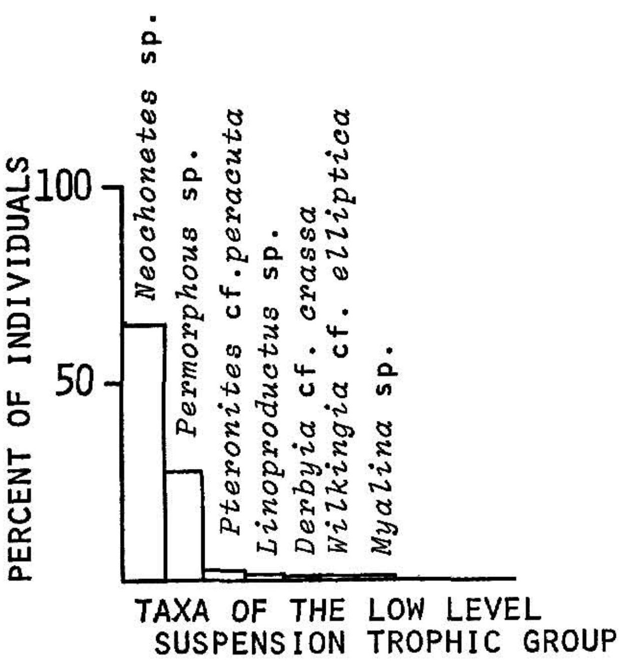


Figure 16. Trophic Structure of the Neochonetes Community.

water depth and distance to shore line, to that of the Neochonetes Community. The community characteristically occupies a narrow zone (1-2 cm) in bed 4 and unit 6-t. Substrate was dominately silt size, probably quartz and clay minerals. Little reworking of the substrate is indicated, therefore the bottom was probably firm.

Biotic Elements.--The biota of the Linoproductus Community is shown in Table 9. Linoproductus sp. dominates the community and is so gregarious that nearly all other organisms are excluded. In unit 6-t, bivalves Wilkingia cf. elliptica, Pteronites cf. peracuta, Myalina sp., and brachiopods Enteletes cf. hemiplicatus and Echinaria cf. moorei were noted but this could be overlap between this community with the overlying Wilkingia-Pteronites Community. Other indigenous members are the gastropod Cyclozoga sp., bivalve Permorphous sp., ostracode Bairdia sp and annelid Spirobus sp. Fragmented and/or disassociated elements are ectoprocts, crinoids and echinoids.

Linoproductids of the community appeared to be preserved in their presumed life orientation. Grant (1966) and Rudwick (1970) have inferred that the profusion of spines on the pedicle valve, served as a stablization device in fine grained sediments.

Excellent preservation and uniformity of distribution of organisms on the bedding planes of beds 4 and 6-t are also characteristic of the Linoproductus Community.

Community Structure.--Table 10 summarizes the relationship between feeding types, mode of life and level of competition in this community. As in the Neochonetes Community, the biota of the Linoproductus Community are concentrated at the primary consumer level. Epifaunal suspension feeders are the dominant species (9 out of 13). Figure 17 illustrates the trophic structure of the Linoproductus Community. Crinoids and ectoprocts dominate

Table 9

Composition of the Linoproductus Community

Taxonomic Entity	No. of Indiv.	Level of Comp.	Feeding Type	Mode of Life	Trophic Group
Ectoproct					
Fenestrate*	4	Primary	Sus.	Epi.	High Sus
Ramose*	8	Primary	Sus.	Epi.	High Sus
Linoproductus sp.	136	Primary	Sus.	Quasi-Inf	Low Sus
Echinaria cf. moorei	1	Primary	Sus.	Quasi-Inf	Low Sus
Cyclozoga sp.	8	Primary	Dep/Scav	Epi.	Epi Dep
Myalina sp.	1	Primary	Sus.	Epi.	Low Sus
Permorphous sp.	16	Primary	Sus.	Epi.	Low Sus
Pteronites cf. peracuta	3	Primary	Sus.	Semi-Inf	Low Sus
Wilkingia cf. elliptica	4	Primary	Sus.	Semi-Inf	Low Sus
Bairdia sp.	352	Primary	Dep.	Nek-Inf	Epi Dep
Crinoid*	138	Primary	Sus.	Epi.	High Sus
Echinoid*	36	Secondary	Pred.	Epi.	-
Spirobus sp.	24	Primary	Sus.	Epi.	Low Sus

*Fragments of individuals.

Table 10

Number of Species According to Feeding Type, Mode of Life and Level of Competition in the *Linoproductus* Community.

Subject	Divisions	Number
Feeding Type	Particulate	-
	Suspension	10
	Deposit	2
	Predator	1
Mode of Life	Epifaunal	9
	Quasi-Infaunal	2
	Semi-Infaunal	2
	Infaunal	-
Level of Competition	Producer	-
	Primary Consumer	12
	Secondary Consumer	1
	Tertiary Consumer	-

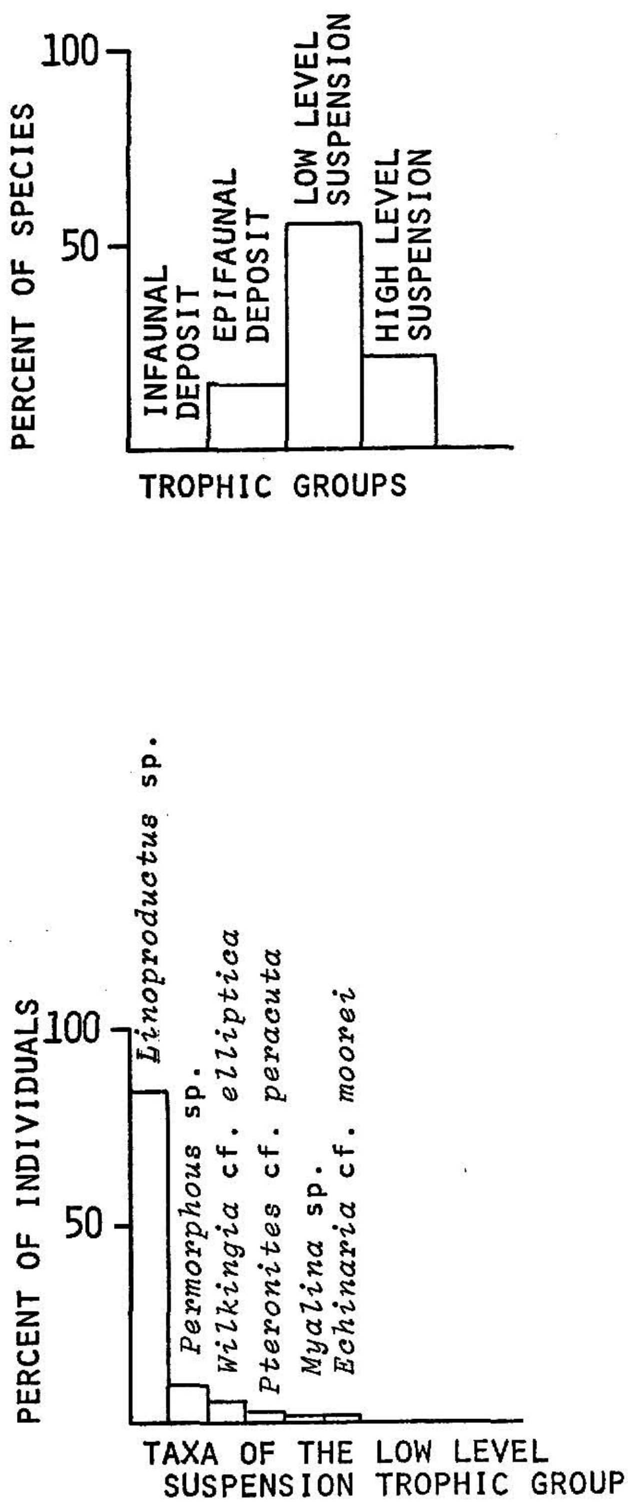


Figure 17. Trophic Structure of the Linoproductus Community.

the high level suspension feeders but their abundance is difficult to establish because they are disassociated. Low level suspension feeders are the dominant trophic group, with Linoproductus sp. the dominant species in this group. Foraminiferids in the Neochonetes Community are absent in this community. There is little direct evidence of species representing producers, secondary consumers (other than echinoids) and tertiary consumers.

Wilkingia-Pteronites Community

Stratigraphically, this community occupies the upper limestone (beds 7, 8, 9 and 10) of the Reading Limestone Member. Total number of species (22) is greater than in the other two communities. The depositional environment is essentially the same as during lower limestone deposition. The substrate was probably less stable than during deposition of middle siltstone because bioturbation is conspicuous (see Appendix 3) in this carbonate mud (micrite) and terrigenous grains are sparce.

Biotic Elements.--Those organisms considered indigenous to the community are listed in Table 11. Dominance in this community is shared by two bivalves Wilkingia cf. elliptica and Pteronites cf. peracuta. Brachiopods are also present (Echinaria cf. moorei, Linoproductus sp., and Enteletes cf. hemiplicatus.) Isolated individuals of Myalina sp., Aviculopecten sp., Neochonetes sp. and gastropods Cyclozoga sp., Bellerophon sp. and Straparollus sp. are also found. Microfossils are foraminiferids Triticites sp., Globivalvulina sp., opthalmids, Ammovertella sp., and the ostracode Bairdia sp. Fragmented and/or disassociated elements are crinoids, echinoids, ectoprocts, trilobites and fish debris.

Members of this community are distributed as isolated individuals, unlike the gregarious distribution of Linoproductus sp. in the underlying community.

Table 11

Composition of the Wilkingia-Pteronites Community

Taxonomic Entity	No. of Indiv.	Level of Comp.	Feeding Type	Mode of Life	Trophic Group
Triticites sp.	2	Primary	Part.	Epi.	Epi Dep
Opthalmid	2	Primary	Part.	Epi.	Epi Dep
Globivalvulina sp.	28	Primary	Part.	Epi.	Epi Dep
Ammovertella sp.	2	Primary	Part.	Epi.	Epi Dep
Ectoproct					
Fenestrate*	11	Primary	Sus.	Epi.	High Sus
Ramose*	31	Primary	Sus.	Epi.	High Sus
Neochonetes sp.	64	Primary	Sus.	Epi.	Low Sus
Linoproductus sp.	62	Primary	Sus.	Quasi-Inf	Low Sus
Enteletes cf. hemiplicatus	37	Primary	Sus.	Epi.	Low Sus
Echinaria cf. moorei	80	Primary	Sus.	Quasi-Inf	Low Sus
Cyclozoga sp.	1	Primary	Dep/Scav	Epi.	Epi Dep
Bellerphon sp.	1	Primary	Dep/Scav	Epi.	Epi Dep
Straparollus sp.	4	Primary	Dep/Scav	Epi.	Epi Dep
Myalina sp.	1	Primary	Sus.	Epi.	Low Sus
Wilkingia cf. elliptica	107	Primary	Sus.	Semi-Inf	Low Sus
Pteronites cf. peracuta	90	Primary	Sus.	Semi-Inf	Low Sus
Aviculopecten sp.	1	Primary	Sus.	Epi.	Low Sus
Ditymopyge sp.*	6	Primary	Dep.	Epi-Inf	Epi Dep
Bairdia sp.	12	Primary	Dep.	Nek-Inf	Epi Dep
Crinoid*	58	Primary	Sus.	Epi.	High Sus
Echinoid*	105	Secondary	Pred.	Epi.	-
Osagia sp.	49	Producer	-	-	-

*Fragments of individuals

Wilkingia cf. elliptica and Pteronites cf. peracuta occur in presumed life position. Comparison of Pteronites cf. peracuta with Pinna carnea, a recent bivalve of the same family, supports the life position inferred for Pteronites cf. peracuta. On the other hand no recent relatives of Wilkingia cf. elliptica exist but the modern bivalve Modiolus modiolus has a similar morphology. Reconstruction of life habits of Wilkingia cf. elliptica must be based on associated fossils and rock type. Observations on lithology, orientation with respect to bedding and functional morphology suggest that it had a mode of life similar to the Upper Silurian bivalve, Grammysia obliqua studied by Bambaugh (1971). Stanley (1970) indicated that strongly ornamented, thick valved shells are required for bivalve stability near the sediment-water interface. The mode of life of Wilkingia cf. elliptica may be more correctly termed semi-infaunal, because like Grammysia obliqua, shell morphology suggests it lacked an extendable siphon which limited bepth of burial. All specimens of Wilkingia cf. elliptica were inclined with respect to bedding, this inclination could be because of their mode of life (i.e. partly buried). Stanley (1970) noted that shallow burrowing bivalves use a rocking motion which introduces a forward component to the burrowing path, resulting in the organism coming to rest inclined with respect to bedding.

Specimens of Pteronites cf. peracuta and Wilkingia cf. elliptica occur in all units of the upper limestone; Linoproductus sp. occurs in beds 9 and 10. Echinaria cf. moorei (62 specimens) occurs in bed 8 (Pearce, 1973) and Neochonetes sp. occurs as isolated individuals in bed 10 at the the contact between the Reading Limestone and Harveyville Shale.

Community Structure.--Table 12 illustrates species abundance in the community of feeding type, mode of life and level of competition. This community is dominated by epifaunal suspension feeding primary consumers.

Table 12

Number of Species According to Feeding Type, Mode of Life and Level of Competition in the *Wilkingia-Pteronites* Community

Subject	Divisions	Number
Feeding Type	Particulate	4
	Suspension	11
	Deposit	5
	Predator	1
Mode of Life	Epifaunal	17
	Quasi-Infaunal	2
	Semi-Infaunal	2
	Infaunal	-
Level of Competition	Producer	1
	Primary Consumer	19
	Secondary Consumer	2
	Tertiary Consumer	-

Figure 18 illustrates the trophic structure of the Wilkingia-Pteronites Community. Suspension feeders dominate the community (fig. 18) and of the suspension feeders and the community, the bivalves Wilkingia cf. elliptica and Pteronites cf. peracuta are the major elements, hence the community name. Other low level suspension feeding species in this community are the brachiopods Echinaria cf. moorei, Linoproductus sp. and Enteletes cf. hemiplicatus. The three species Wilkingia cf. elliptica, Pteronites cf. peracuta and Echinaria cf. moorei occur in the same trophic group and are thus in direct competition for the same resources. Three explanations may be that (1) further subdivision of food resources prevents competition, (2) feeding type and mode of life of one or all of these species require revision and/or (3) resources were abundant enough to support vigorous competition.

Crinoids and ectoprocts are the only high level suspension feeders, the gastropods Cyclozoga sp., Bellerphon sp. and Straparollus sp. dominate the epifaunal deposit feeders. Again little evidence suggests the presence of producers, secondary consumers or tertiary consumers in this community other than a few fish remains.

RELATIONSHIPS BETWEEN DEPOSITIONAL ENVIRONMENTS AND BENTHIC COMMUNITIES

General Statement

Three fossil benthic communities are recognizable during deposition of the Reading Limestone: (1) Neochonetes Community, (2) Linoproductus Community and (3) Wilkingia-Pteronites Community (fig. 19). Differentiation amoung communities is a function of taxonomic substitution in the trophic structure. Taxonomic changes most evident in all three occur in the primary consumers, specifically within the low level suspension feeding trophic group. Therefore,

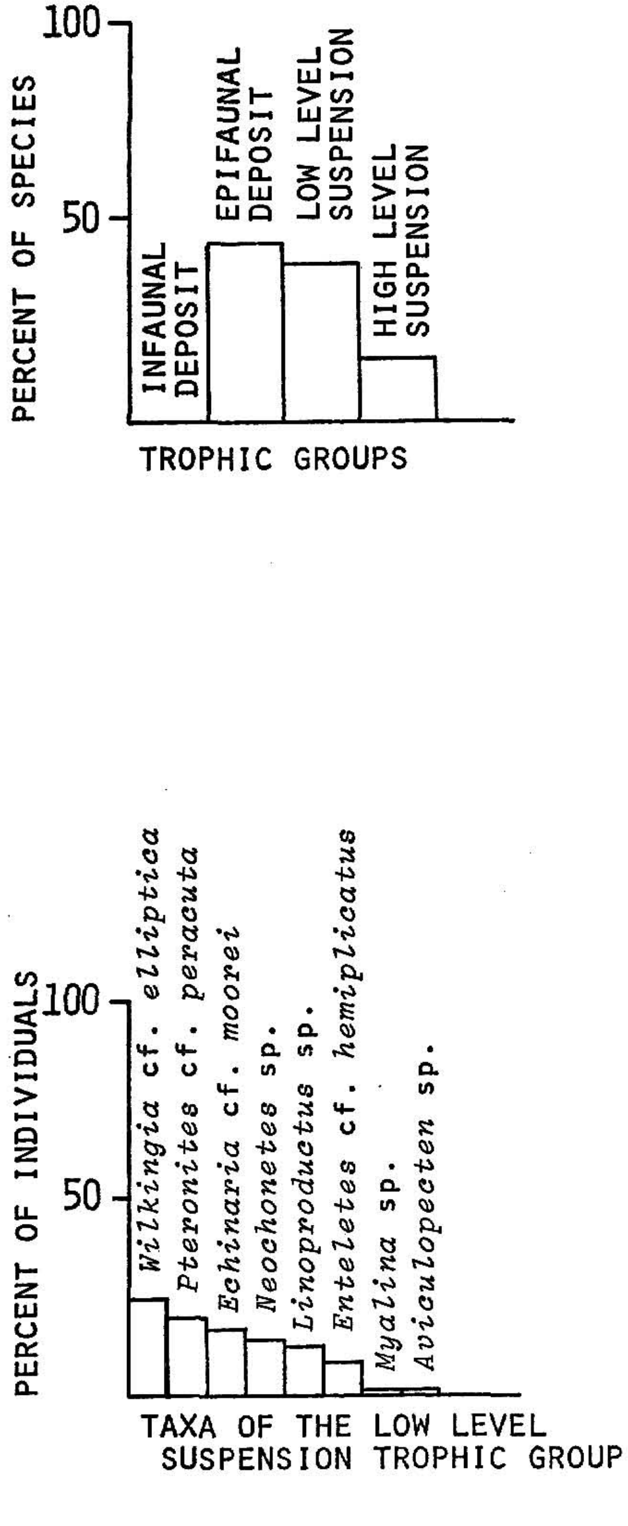


Figure 18. Trophic Structure of the Wilkingia-Pteronites Community.

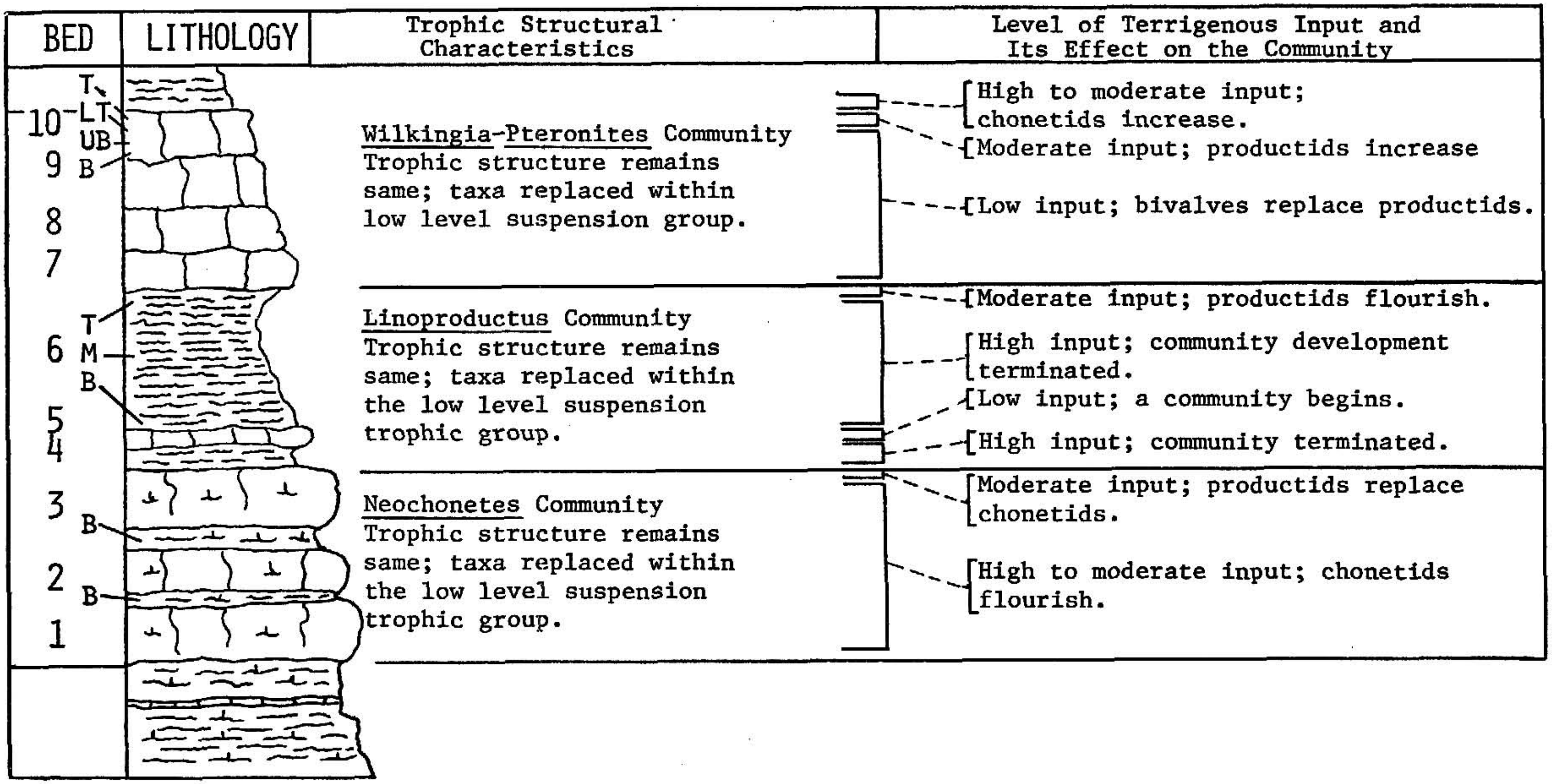


Figure 19. Characteristics of Community Transition During Reading Limestone Deposition.

suitability of the zone immediately above the sediment-water interface is of major importance. This suitability is a function of sedimentation rates, types of sediment and/or sediment stability (waves, currents, bioturbation, etc.). Appearance and decline of each of the communities can be explained by these parameters.

Neochonetes Community

This community occurs in the lower limestone of the Reading Limestone, specifically in the thin siltstone beds 2b and 3b and *Neochonetes* sp. is the dominant species. The associated environment is suggested to have been one of shallow, low energy, carbonate deposition, with moderate quantities of terrigenous influx. Organism preference for this environment was probably related to food availability and suitability of the substrate for settlement. For example, if terrigenous input was too high, benthic organisms could be buried or their feeding mechanisms clogged. In food gathering ability there would have been direct competition between linoproductids and chonetids, but some environmental parameter was detrimental to the linoproductids. Therefore, propogation of the *Neochonetes* Community must have been related to the settlement capability of the chonetids on a substrate unsuitable to linoproductids and bivalves. Specimens of *Neochonetes* sp. collected from the base of bed 2 populated the environment represented by the upper part of unit 1. The sample of this population is interpreted to represent a normal occurrence of this species in terms of natality and mortality. At that time terrigenous input was at a high level (31 percent insolubles) for these limestones. When the population was sampled again at the base of bed 3, it is interpreted to be declining, possibly because of different rates of natality and mortality. Additional data (Pearce, 1973) indicates that chonetids reappear in unit 10-t (contact of the Reading Limestone and Harveyville Shale) where insolubles comprise 25 percent of the unit.

Two factors may relate to the chonetids adaptation to an environment high in terrigenous components. First, chonetids are smaller and weigh less therefore they are not as likely to sink into the substrate as larger heavier organisms. Second, their mode of life probably ranged from epifaunal to nektonic if one accepts Rudwick's (1970) interpretation of their life habits. He suggested that a snapping action of the valves was used to clear sediment and was used for transportation. Rudwick (1970) also suggested that the spines along the hinge line were used as a sensory mechanism. Boger (1968, p. 127-129) suggested that these spines were a counter balance to maintain the organism's center of gravity. These spines could have served both functions.

A consequence of flexibility in mode of life is that the organism is not restricted to the low level suspension feeding category. If it only feeds at that level, its mobility would increase its food gathering capability by enabling them to search over a greater bottom area. Finally, mobility allowed migration in the face of competition or adverse environmental conditions, serving as an escape mechanism.

Decline and disappearance of the Neochonetes Community is linked to environmental change. During deposition of bed 1, only chonetids were fully adapted to utilizing resources in a turbid carbonate environment. As soon as the environment began to clear, other organisms appeared that were capable of competing with the chonetids. If this is true, why didn't the community reappear in bed 4? Possibly sedimentation rates were different and environmental requirements of chonetids may have passed rapidly preventing propogation of the community. It was not until unit 10-t that favorable conditions were reestablished.

Linoproductus Community

This community inhabited the middle siltstone. The main difference between this community and the Neochonetes Community is that Linoproductus sp. replaces Neochonetes sp. as the dominant low level suspension feeder. The community specifically was found within bed 4 and at the contact of bed 6 and bed 7. Insoluble data indicate that turbid conditions (56 percent insolubles) dominated the area during deposition of bed 4. A possible explanation for the community in this bed in an environment of probably lethal levels of sedimentation (lethal inplying burial or clogging of feeding mechanisms) is that optimum conditions for Linoproductus sp. settlement probably were closer to those environmental parameters of bed 3 (15 percent insolubles). Why then were there so many linoproductids in bed 4? All linoproductids found in bed 4 are large individuals (i.e. mature). This implies that substrate suitability or resource availability for new generations was lowered and recruitment failed. Organisms already established reached mature size but were eventually killed by conditions represented by bed 4.

Bed 5 represents a period during which carbonate sedimentation predominated with little terrigenous influx (8 percent insolubles). Lithologic parameters indicate that this was a favorable environment for propogation of a community because similar lithologic parameters of the upper limestone and lower limestone promoted community development. Absence of a community in bed 5 occurs because optimum conditions necessary for Linoproductus sp. or Neochonetes sp. probably did not last long enough. Foraminiferid, ostracode and juvenile assemblages of bivalves and gastropods on the upper surface of bed 5 suggest a community in the initial stages of development, but that development was terminated by the influx of terrigenous sediments (64 percent insolubles in unit 6-b). The Linoproductus Community reappears during the transition from terrigenous deposition (6-t) to carbonate deposition (bed 7) because favorable bottom conditions returned as the terrigenous influx and/or turbidity decreased. Decline of the Linoproductus Community is related to the return of a carbonate depositional environment (upper limestone). Absence of linoproductids in bed 7 suggests that the substrate of this bed was not favorable for gregarious settlement of this species. Substrate suitability and/or resource availability could have been responsible for their absence. A bioturbated carbonate substrate may have been too fine grained and too soupy to support them and/or prevented settlement of juvenile forms. Linoproductids in the upper limestone are large individuals, therefore failure of this community was probably a function of high infant mortality during settlement (inadequate substrate, disease, food absent, etc.). Additional data (Pearce, 1973) indicate that favorable conditions for linoproductids (reflected in the number of linoproductids in unit 10-t, 40 individuals as opposed to 9 in bed 9) may have been returning near the end of Reading Limestone time.

Wilkingia-Pteronites Community

In the upper limestone (beds 7-10), Wilkingia cf. elliptica dominates the community. However, specimens of Pteronites cf. peracuta are almost equally abundant. The major change in community structure is that the low level suspension trophic group is now dominated by bivalves rather than brachiopods. Less conspicuous, but an equally significant change, is the increase in species abundance in the low level suspension feeders (13 upper limestone, 8 middle siltstone and 12 lower limestone). Presumably these changes in representative taxa of the community structure are related to changes in parameters of the depositional environment. The upper limestone was the time of least terrigenous influx and greatest amount of carbonate deposition. Perhaps these conditions are responsible for a substrate more favorable not only for supporting semi-infaunal bivalves (*Wilkingia* cf. *elliptica* and *Pteronites* cf. *peracuta*) but also increasing overall abundance of species and individuals.

The *Wilkingia*-*Pteronites* Community appears to decline in response to a reversal of the same conditions responsible for its appearance. In the upper limestone (in unit 10-t) insolubles are high (25 percent) possibly terrigenous influx of the initial stages of deposition of the Harveyville Shale.

Mechanisms of Community Transition

Five conclusions regarding community transition common to benthic marine communities of the Reading Limestone Member of the Emporia Limestone are:

(1) The major part of the community structure is concentrated at the primary consumer level. This might represent preservational bias, but comparisons with recent benthic marine communities indicates that concentration at the primary consumer level is probably valid.

(2) Differences in these communities are the result of different taxa in the community structure rather than any changes in structure.

(3) Favorable environmental conditions must exist and exist long enough for these communities to develop completely.

(4) Changes of taxa in the community structure are related to the species capability of responding to changes in environmental conditions.

(5) The most important definable environmental parameters are the

relative amount and kind of sedimentation. The sensitivity of different species to these parameters is reflected in these communities.

Summary

Figure 20 summarizes the findings of the original four objectives (define the environments and benthic communities, relate the two and define some of the mechanisms and responses of the communities to environmental change). The environment during deposition of the Reading Limestone has been inferred to be a low energy carbonate depositional environment (upper and lower limestones) with one major terrigenous influx (middle siltstone) interrupting carbonate deposition on a shallow lagoon and/or embayed shelf. Three major fossil benthic communities are recognizable. By relating the environment to these fossil communities (fig. 20), the generalized conclusion was that when the environment changed, an existing fossil community was replaced by another fossil community. Functional morphological interpretations and trophic reconstructions permitted inferences on the mechanisms of community transition. By referring to the specifics of what constitutes environmental change, it is suggested that terrigenous influx had the greatest effect on determination of environmental conditions, which also had the effect of promoting community transition.

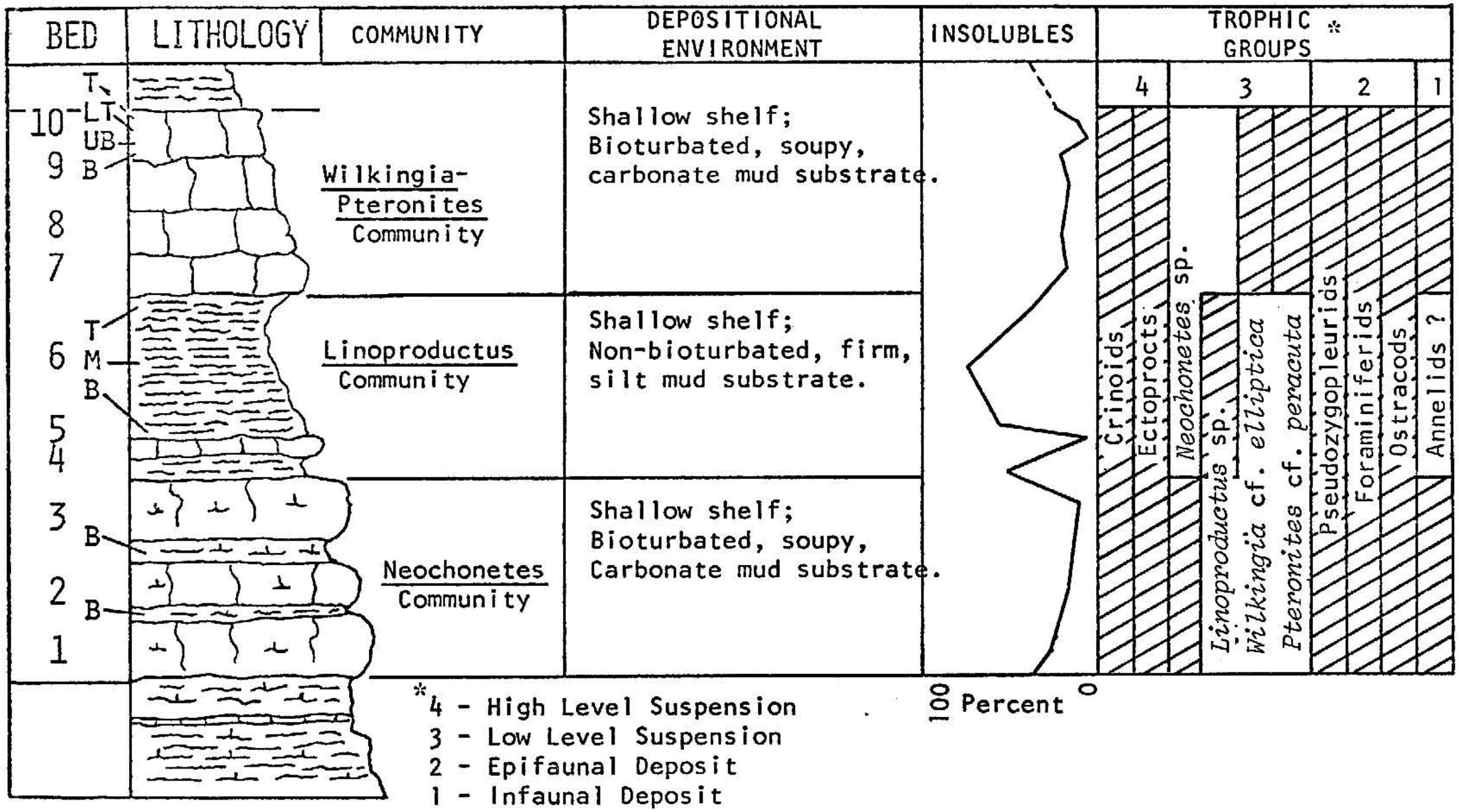


Figure 20. Generalized Biologic and Sedimentologic Characteristics of the Reading Limestone.

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APPENDIX 1

Location and Description of Measured Section

Location

The section below is exposed at site 18 (fig. 5) in the spillway of the Atchison County Lake. The spillway lies in three 2½ acre tracts, the NW¼, NW¼, SW¼, NE¼, the NE¼, NE¼, SE¼, NW¼ and also the SE¼, SE¼, NE¼, NW¼ all of Sec. 12, T. 5 S., R. 17 E., Atchison County, Kansas.

Description

Bed	Thickness (ft.)
Lower Limestone	2.3 (total)
Bed 1	0.75
Bed 2	0.40
Bed 3	0.67

Lithology

Limestone (carbonate mudstone), persistent, thin to medium bedded, three beds, separated by platy to fissil dark gray (N3) to olive gray (5Y 4/1) siltstone partings, .33 foot and .17 foot thick. Limestone dense, argillaceous, undulating subparallel bedding, blocky to subconchoidal fracture; upper contact gradational to sharp with bed 4; lower contact with Auburn Shale is gradational; joints in upper bed 3.

Color

Unweathered Dry - medium light gray (N6) to light olive gray (5Y 6/1).
Unweathered Wet - medium dark gray (N4) to olive gray (5Y 4/1).
Weathered Dry - yellowish gray (5Y 7/2), dusky yellow brown (10YR 2/2) and light brown (5YR 5/6).
Weathered Wet - medium dark gray (N4) to olive gray (5Y 4/1).

Biotic Components

Fossiliferous, particularly in siltstone partings; on upper surface of bed 3 are numerous linoproductid molds; also in bed 3 are isolated incomplete specimens of *Pteronites* cf. *peracuta* and *Myalina* sp.; bed 2 contains *Wilkingia* cf. *elliptica*, *Pteronites* cf. *peracuta*, *Myalina* sp. and *Neochonetes* sp. Dominating the siltstone partings were *Neochonetes* sp. and crinoid debris; *Wilkingia* cf. *elliptica*, *Pteronites* cf. *peracuta* and *Linoproductus* sp. occur in life position. Celestite replacement occurred throughout the lower limestone,

Description

Bed | Thickness (ft.)

Biotic Components (cont.)
usually replacing bivalve shells.

Representatives from washed residues of the siltstone partings, thin sections, etched section and bedding plane study are:

Globivalvulina sp.
Opthalmids
Endothyra sp.

Osagia sp.

Ectoprocts (fenestrate, ramose)
Crinoid debris (columnals)
Echinoid debris (plates, spines)

Neochonetes sp.
Linoproductus sp.

Derbyia cf. crassa
Neospirifer sp.

Myalina sp.
Permorphous sp.
Pteronites cf. peracuta
Wilkingia cf. elliptica

Ditymopyge sp.

Bairdia sp.

Middle Siltstone
(Beds 4, 5 and 6) 2.1 (total)

Bed 4 0.2

Lithology

Siltstone, calcareous, persistent, platy to thin bedded; sharp to gradational wavy upper and lower contacts; poor outcrop, only observed in the spillway.

Color
Unweathered Dry - light gray (N7).
Unweathered Wet - brownish black (5YR 2/1).
Weathered Dry - light gray (N7).
Weathered Wet - brownish black (5YR 2/1).

Biotic Components

Fossiliferous; "in situ" linoproductids, some spines are 1.5 inches long. Fossils in washed residues and on bedding planes are:

Ectoprocts (fenestrate, ramose)
Crinoid debris (columnals)
Echinoid debris (plates, spines)

Linoproductus sp.

Cyclozoga sp.
Permorphous sp.

Bairdia sp.

Spirobus sp.

Description

Bed | Thickness (ft.)

Middle Siltstone (cont.)

Bed 5 0.6

Lithology

Limestone, coquinidal, persistent, platy to thin bedded, parallel alignment of platy fossil fragments produces laminated appearance; upper contact sharp, lower contact gradational; poor outcrop.

Color

Unweathered Dry - olive gray (5Y 4/1) to moderate yellowish brown (10YR 5/4).
Unweathered Wet - medium dark gray (N4) to dark gray (N3).
Weathered Dry - olive gray (5Y 4/1) to pale yellowish brown (10YR 6/2).
Weathered Wet - medium dark gray (N4) to dark gray (N3).

Biotic Components

Thin sections revealed:

Opthalmids
Bairdia sp.

Fish tooth

Bed 6 1.7

Lithology

Siltstone, calcareous, regular bedder, platy, blocky fracture, sharp basal contact, marked by 1-2 mm thick zone of ferrigenous cemented microfossils (foraminiferids and ostracodes); upper contact gradational, marks zone of abundant "in situ" linoproductids; weathered back sharply under the upper limestone; poor outcrop and observed only in spillway.

Color

Unweathered Dry - light olive gray (5Y 6/1) to medium dark gray (N4).
Unweathered Wet - olive gray (5Y 4/1) to dark gray (N3).
Weathered Dry - light olive gray (5Y 4/1) to medium dark gray (N4).
Weathered Wet - olive gray (5Y 4/1) to dark gray (N3).

Biotic Components

Fossiliferous at lower contact and in upper .1 to .2 feet; fossils in washed residues and on bedding planes are:

Description

Bed | Thickness (ft.)

Middle Siltstone

Bed 6

Biotic Components (cont.)

Endothyra sp.
Ammovertella sp.

Ectoprocts (fenestrate, ramose)
Crinoid debris (columnals)
Echinoid debris (plates, spines)

Linoproductus sp.
Derbyia cf. crassa
Echinaria cf. moorei

Myalina sp.
Permorphous sp.
Wilkingia cf. elliptica
Pteronites cf. peracuta
Aviculopecten sp.

Bairdia sp.
Geisina sp.
Hollinella sp.
Paraparchites sp.

Upper Limestone
(Beds 7, 8, 9 and 10) — 2.3 (total)

Lithology

Limestone (carbonate mudstone), algal-crinoidal, 4 distinct, persistant, subparallel beds, separated by fracture zones in beds 9 and 10 and by irregular, thin (less than .1 foot thick) claystone partings in the lower beds 7 and 8. Overall thick bedded, dense, resistant, finely crystalline, argillaceous to micaceous in bed 7 and algal structures (Osagia coated skeletal debris) dominant in the upper (8, 9 and 10) beds. Joint system well developed; upper contact sharp, marked by .1 foot platy, silty carbonate mudstone, overlain by the siltstone of the Harveyville Shale. Lower contact gradational. The upper limestone is the most resistant unit of the Reading Limestone and is the bed most often observed in outcrop. It is commonly referred to as the "red top" limestone and contains large weathered depressions (Wilkingia cf. elliptica molds).

Bed 7 — 0.4

Color

Unweathered Dry - light gray (N7) to medium light gray (N6).
Unweathered Wet - dark gray (N3) to grayish black (N2).
Weathered Dry - light brown (5YR 5/6) to moderate yellowish brown (10YR 5/4).
Weathered Wet - moderate yellowish brown (10YR 5/4) to dark gray (N3).

Bed 8 — 0.5

Color

Unweathered Dry - medium gray (N5) to medium light gray (N6).

Description

Bed | Thickness (ft.)

Upper Limestone

Bed 8 (cont.)

Color

Unweathered Wet - medium gray (N5) to medium dark gray (N4).

Weathered Dry - moderate yellowish brown (10YR 5/4), dark yellowish orange (10YR 6/6) to pale yellowish orange (10YR 8/6); some moderate brown (5YR 4/4) banding.

Weathered Wet - moderate yellowish brown (10YR 5/4) to dark gray (N3).

Bed 9 — 0.6

Color

Unweathered Dry - dark gray (N3) to dusky yellowish brown (10YR 2/2).

Unweathered Wet - grayish black (N2) to dusky yellowish brown (10YR 2/2).

Weathered Dry - iron stained, medium yellow brown (10YR 5/4), dark yellowish orange (10YR 6/6) and pale yellowish orange (10YR 8/6).

Weathered Wet - light brown (5YR 5/6) to moderate yellowish brown (10YR 5/4).

Bed 10 — 0.8

Color

Unweathered Dry - dark gray (N3) to dusky yellowish brown (10YR 2/2).

Unweathered Wet - grayish black (N2) to brownish black (5YR 2/1).

Weathered Dry - iron stained, medium yellow brown (10YR 5/4), dark yellowish orange (10YR 6/6), and pale yellowish orange (10YR 8/6).

Weathered Wet - light brown (5YR 5/6) to moderate yellowish brown (10YR 5/4).

Biotic Components

Fossil debris increases upward. Crinoid and algal debris are dominant. Celestite replaces some gastropod and bivalve shells; most significant are *Wilkingia* cf. *elliptica* and *Pteronites* cf. *peracuta* specimens preserved in presumed life position. Other less frequently noted "in situ" specimens are *Linoproductus* sp. and *Echinaria* cf. *moorei*. Thin sections, bedding planes and etched sections revealed the following fossils:

Description

Bed | Thickness (ft.)

Upper Limestone

Biotic Components (cont.)

Triticites sp.
Globivalvulina sp.
Opthalmids
Ammovertella sp.

Osagia sp.

Ectoprocts (fenestrate, ramose)
Crinoid debris (columnals)
Echinoid debris (plates, spines)

Neochonetes sp.
Linoproductus sp.
Enteletes cf. hemiplicatus
Echinaria cf. moorei

Derbyia cf. crassa

Cyclozoga sp.
Bellerophon sp.
Straparollus sp.

Myalina sp.
Pteronites cf. peracuta
Wilkingia cf. elliptica
Aviculopecten sp.

Bairdia sp.

Fish tooth

Total thickness of Reading Limestone - 6.7 feet

APPENDIX 2

Disaggregation Data

Introduction.--Disaggregation data are listed below. It was obtained after the samples had been seived into fractions. Only the +10, +18 and +35 fractions were sorted for their organic content. In some samples the organic content was too large, most frequently in the +35 fraction, to identify every item. Therefore, a sample splitter was employed. In the columns below, the size of the split fraction per each sample, if used, is indicated. The total number of biotic elements indicated or total number of individuals in a specific taxa are the result of the number found in the split sample times the denominator of the fraction.

Numbers of Organisms Per Unit and Fraction

Unit:	Bed 2-b			Bed 3-b		
Fraction:	+10	+18	+35	+10	+18	+35
Split fraction:	-	1/4	1/64	-	1/4	1/128
Organism						
ECTOPROCTA						
Ramose	17	28		19	44	
BRACHIOPODA						
Neochonetes sp.	38	12	64	26	4	

Of the 114 total specimens in bed 2-b, 12 percent were brachial valves, 81 percent were pedicle valves and 7 percent were articulated. Of the 30 total specimens in bed 3-b, 50 percent were brachial valves, 43 percent were pedicle valves and 7 percent were articulated.

Organism	+10 (2-b)	+18 (2-b)	+35 (2-b)	+10 (3-b)	+18 (3-b)	+35 (3-b)
Derbyia cf. crassa	2					
Neospirifer sp.				3		
Fragments	13	1120		18	1132	
MOLLUSCA						
Gastropoda						
Loxonoma sp.		1				
Bivalvia						
Permorphous sp.			64			
Pteronites cf. peracuta				3		
Wilkingia cf. elliptica				1		
Myalina sp.				1		

Unit:	Bed 2-b (cont.)			Bed 3-b (cont.)		
Fraction:	+10	+18	+35	+10	+18	+35
Split fraction:	-	1/4	1/64	-	1/4	1/128
Organism						
ARTHROPODA						
Ditymopyge sp.		4				
Bairdia sp.		12	384		20	1408
ECHINODERMATA						
Crinoid				225	312	
Echinoid				14	240	
Shell debris				482	16	

Unit:	Bed 4		Bed 6-b	
Fraction:	+18	+35	+18	+35
Split fraction:	1/4	1/8	1/4	1/128
Organism				
FORAMINIFERIDA				
Endothyra sp.			56	1280
Ammovertella sp.			8	256
ECTOPROCTA				
Fenestrate			4	
Ramose		8		
BRACHIOPODA				
Linoproductus sp. fragments	2772	3368		
Fragments				640
MOLLUSCA				
Gastropoda				
Cyclozoga sp.		8	12	4608
Loxonoma sp.				384
Bivalvia				
Permorphous sp.		16	136	6912
Myalina sp.			8	128
ANNELIDA				
Spirobus sp.		24	48	128
ARTHROPODA				
Bairdia sp.		352	40	4224
Geisina sp.			40	7552
Hollinella sp.			4	
Parapachites sp.			4	
Cavellina sp.			8	640

Unit:	Bed 4 (cont.)		Bed 6-b (cont.)	
Fraction:	+18	+35	+18	+35
Split fraction:	1/4	1/8	1/4	1/128
Organism				
ECHINODERMATA				
Crinoid		8		128
Echinoid	4	32		
Shell debris	12	80		

Unit:	Bed 6-m	
Fraction:	+18	+35
Split fraction:	1/4	1/64
Organism		
FORAMINIFERIDA		
Ammovertella sp.		64
BRACHIOPODA		
Fragments	140	
ANNELIDA		
Spirobus sp.		64
ARTHROPODA		
Bairdia sp.	12	960
Hollinella sp.		64
Parapachites sp.		256
ECHINODERMATA		
Crinoid	24	

APPENDIX 3a

Etched Vertical Section Data: Quantative Biota

Bed: 1

No. of 20 mm sq.	*Osagia* coated skeletal debris	Crinoid debris	Other skeletal debris
	Organism		
7 (top)			
6		2	
5			6
4	14	4	15
3	2	10	10
2		1	10
1 (base)		2	1
Totals:	16	19	42

Rock name: Biomicrite

Comments: Bioturbated; concentrations of coarse debris.

Bed: 2

No. of 20 mm sq.	Crinoid debris	Linoproductid shell debris	*Bairdia* sp.	Other skeletal debris
4 (top)			2	15
3	2	1		10
2	1			3

THE FOLLOWING PAGE IS BLURRY DUE TO DOUBLE PRINTING IN THE TEXT.

THIS IS AS RECEIVED FROM THE CUSTOMER.

Bed: 2 (cont.)

No. of 20 mm sq.	Crinoid debris	Linoproductid shell debris	*Bairdia* sp.	Other skeletal debris
1 (base)	1			10
Totals:	4	1	2	38

Rock name: Biomicrite

Comments: Entive bed shows disorientation suggesting bioturbation.

Bed: 3

No. of 20 mm sq.	Crinoid debris	Echinoid debris	Linoproductid shell debris	Linoproductid spines	Other skeletal debris
8 (top)	3				
7	A*	2	11	5	21
6	14	12	A	7	9
5	17	9	A	3	15
4					
3	2				
2	1		1	10 ("in situ" linoproductid)	
1 (base)	1		1	2	
Totals:	48	23	13	27	45

Rock name: Biomicrite

Comments: Bioturbation concentrated at level of squares 5, 6 and 7; granular reworked surface at 5.

*Whenever an "A" is used, the entity is abundant or represents over 50 percent by visual estimation of the bioclastic components within one of the squares (20mm x 20mm).

Bed: 7

No. of 20 mm sq.	Crinoid debris	Linoproductid shell debris	Echinoid debris	Other skeletal debris
7 (top)		3 (brachial valves; concave down)		
6	3			1
5	2		2	
4	1			
3	2			
2	4	2 ("in situ" linoproductids)		
1 (base)	3	1		
Totals:	15	6	2	1

Rock name: Biomicrite

Comments: Relatively undisturbed micrite; some bioturbation; limonitic weathered zone at the top.

Bed: 8

No. of 20 mm sq.	*Osagia* coated skeletal debris	Crinoid debris	*Bairdia* sp.	Other skeletal debris
8 (top)		2		A
7		2	3	A
6				A
5		1		
4				5
3		3		

Bed: 8 (cont.)

No. of 20 mm sq.	*Osagia* coated skeletal debris	Crinoid debris	*Bairdia* sp.	Other skeletal debris
2	2	5		
1 (base)			1	
Totals:	2	13	4	5

Rock name: Biomicrite

Comments: Bioturbated throughout.

Bed: 9

No. of 20 mm sq.	*Osagia* coated skeletal debris	Crinoid debris	*Bairdia* sp.	Other skeletal debris	Burrowing
8 (top)		18	1		
7		7			
6		2		1	
5	2	1			
4	2	3	1		1
3	2		2		
2	A	20		15	
1 (base)	A	31		11	
Totals:	6	82	4	27	1

Rock name: Algal-crinoidal biomicrite.

Comments: Bioturbated.

Bed: 10

No. of 20 mm sq.	*Osagia* coated skeletal debris	Ectoproct, fenestrate	Crinoid debris	Echinoid debris	*Bairdia* sp.	Other skeletal debris
12 (top)	6		15			A
11	1		1			A
10	2		2			A
9			7			
8			5			2
7			4			2
6			1			6
5	5		2			
4	5		7			
3	16		13			7
2	31		5			19
1 (base)	41	1	19	1	1	20
Totals:	107	1	81	1	1	56

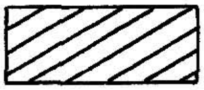
Rock name: Algal-crinoidal biomicrite

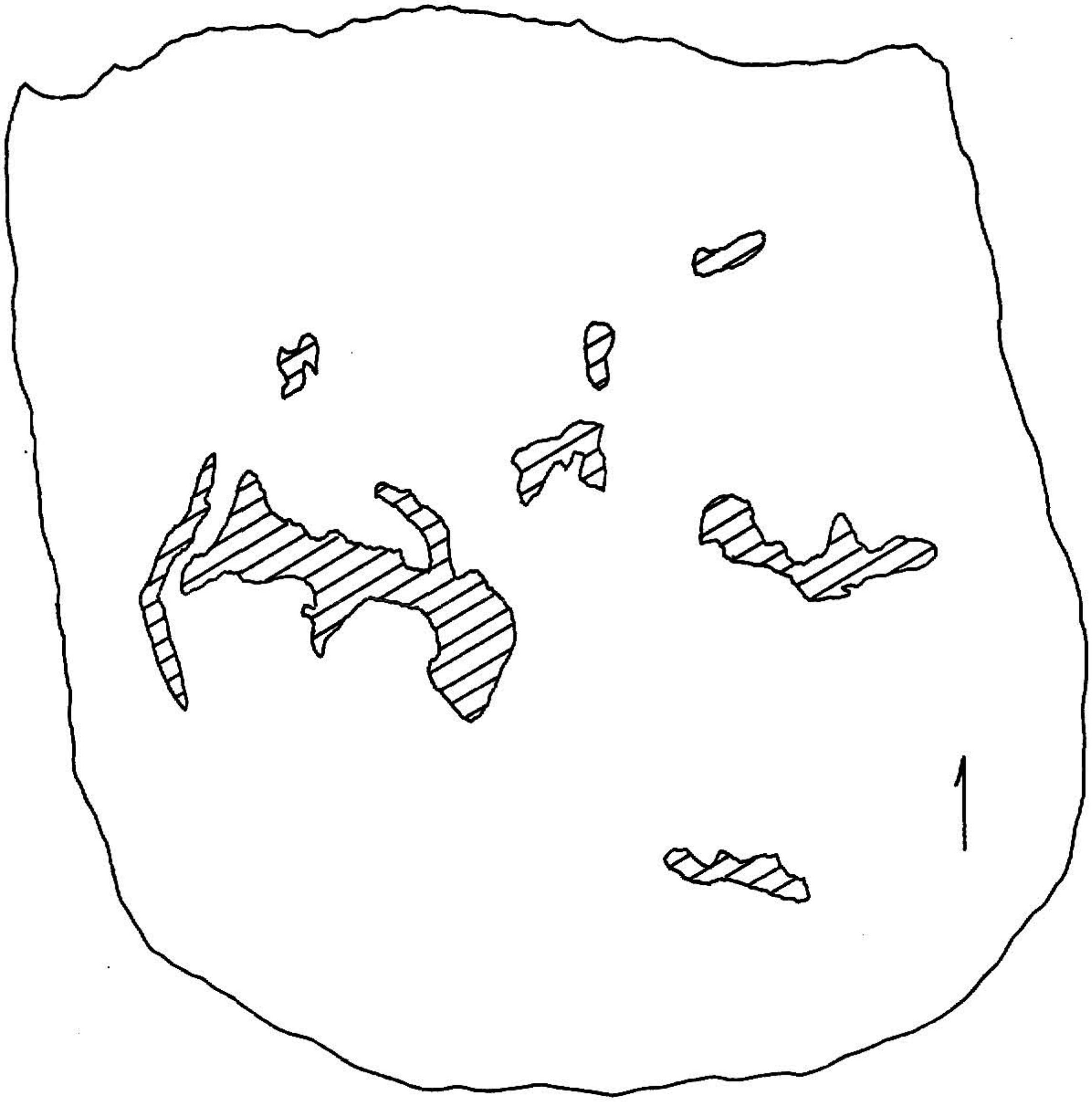
Comments: Bioturbated; rock represents clean, agitated carbonate environment.

APPENDIX 3b

Etched Vertical Section Data: Bioturbation Examples

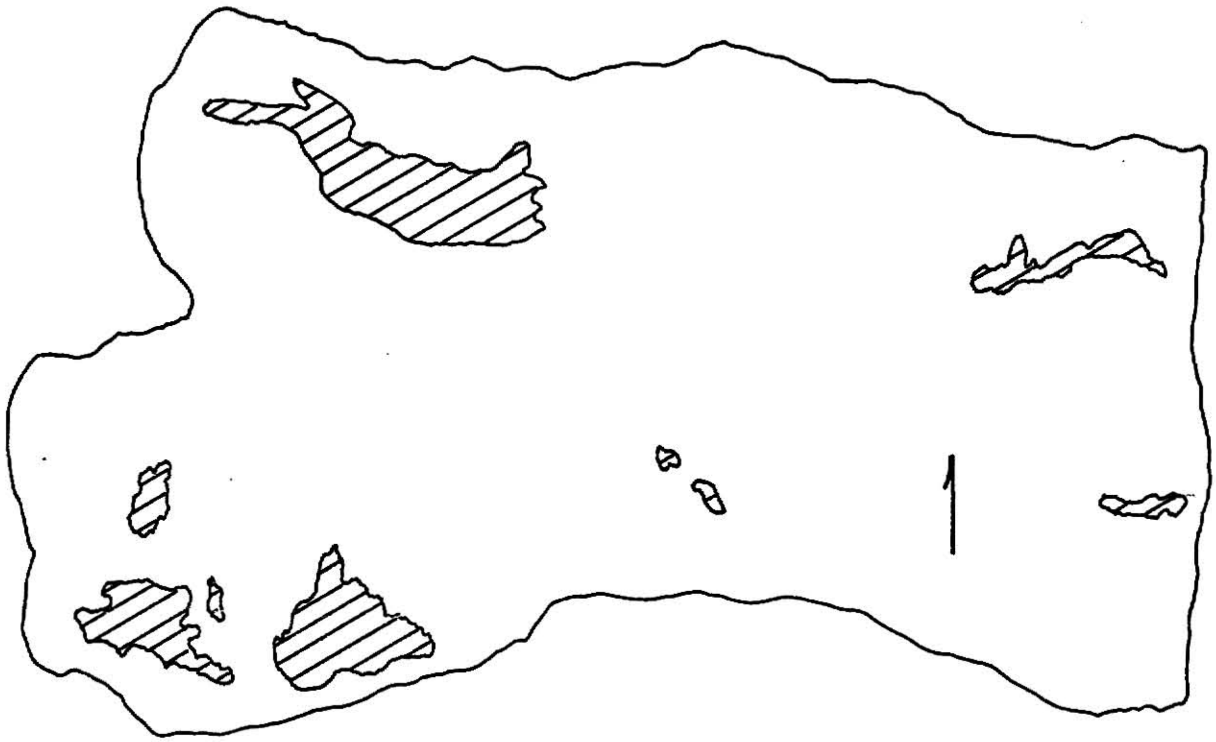
Bed: 1
Scale: Actual size.

Filled Burrow: 

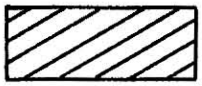


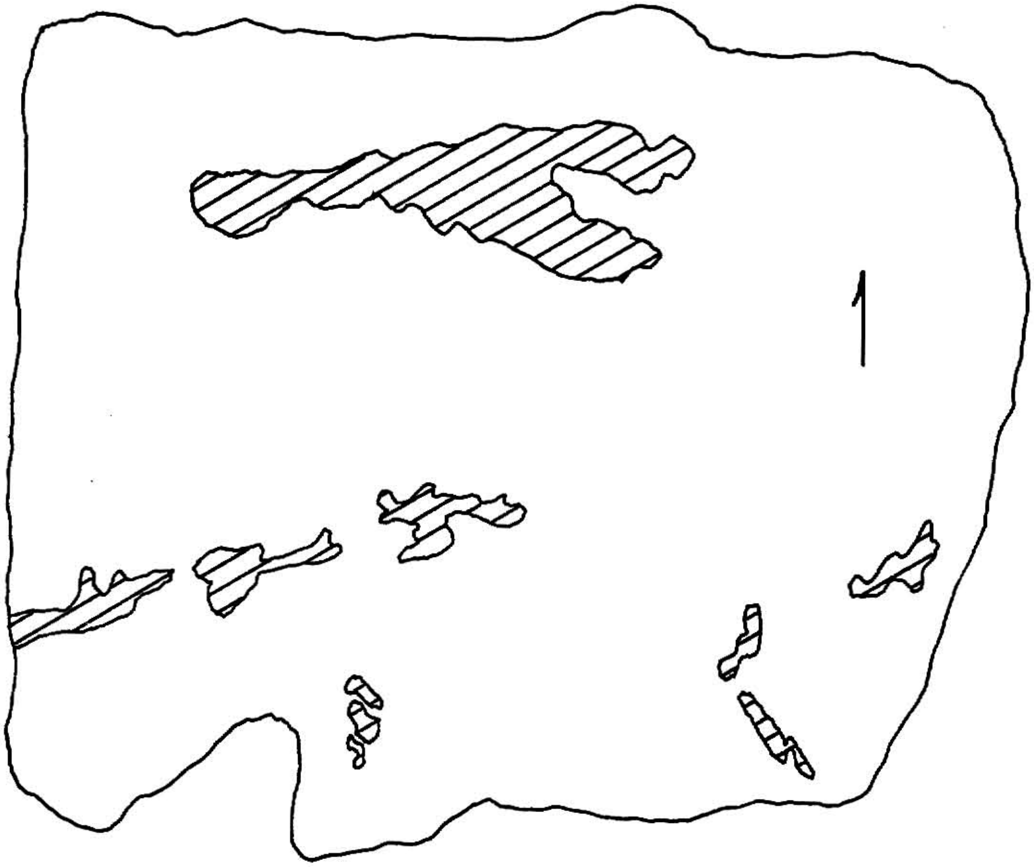
Bed: 2
Scale: Actual size.

Filled Burrow:

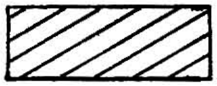


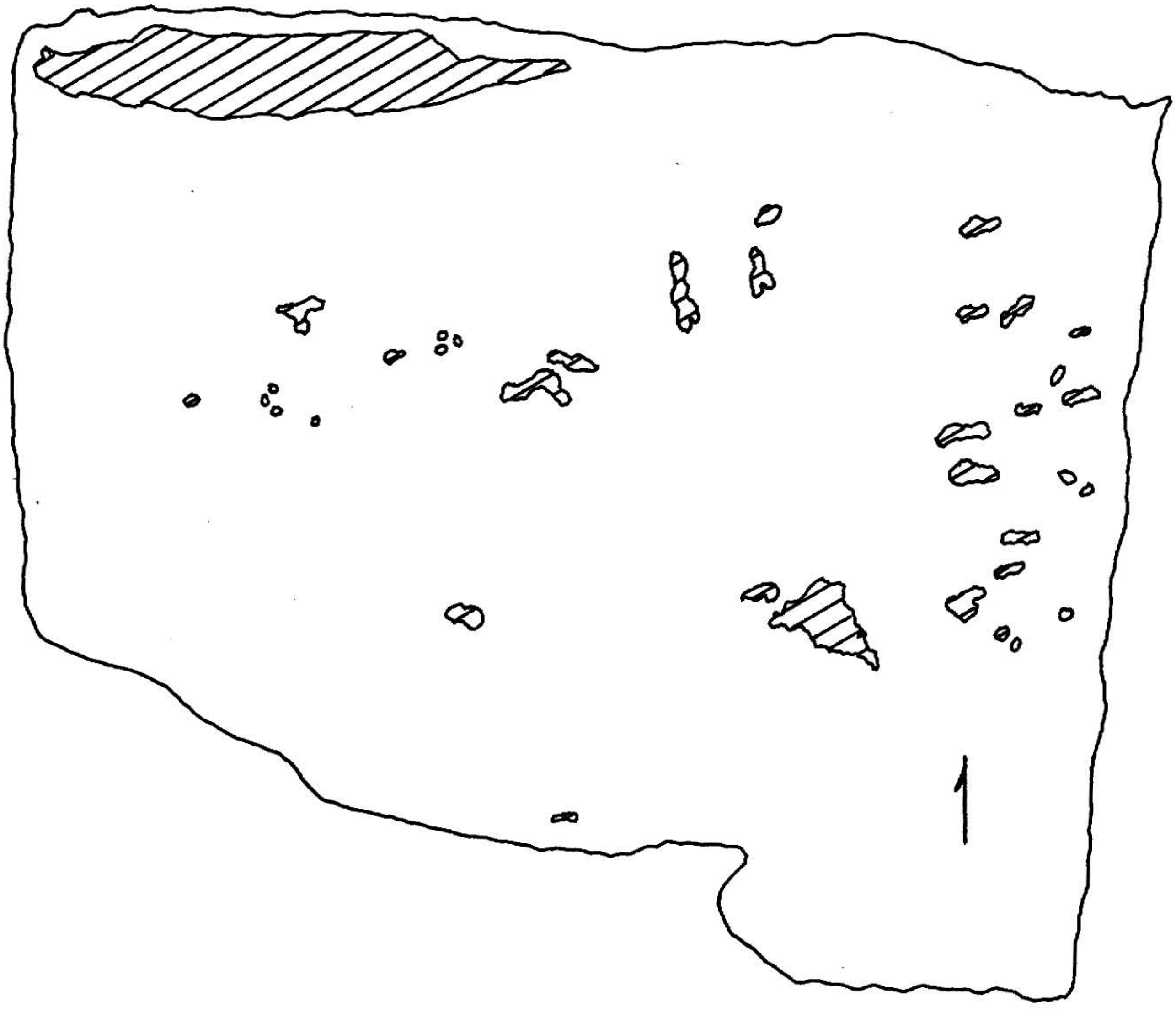
Bed: 3
Scale: Actual size.

Filled Burrow: 



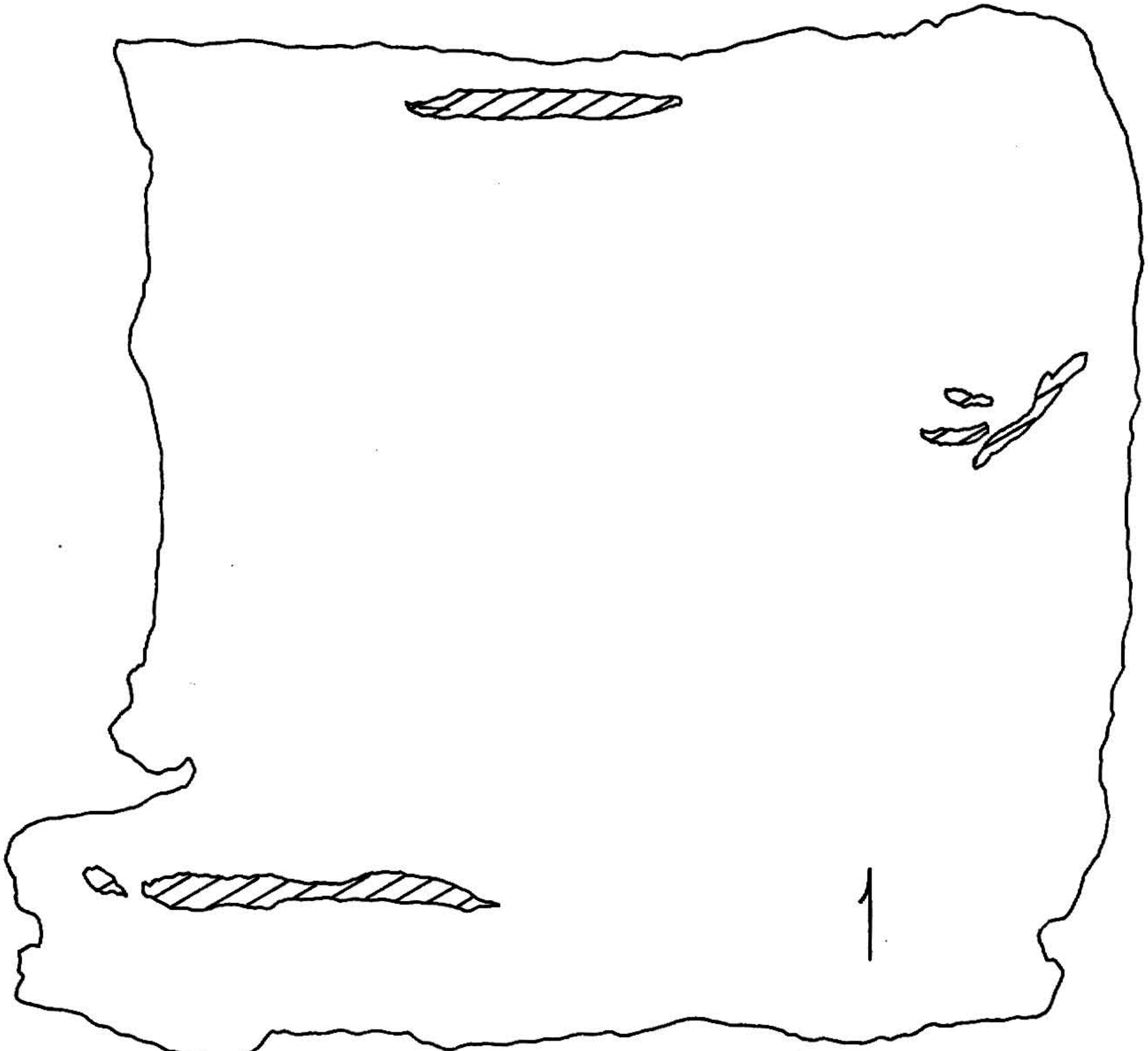
Bed: 7
Scale: Actual size.

Filled Burrow: 

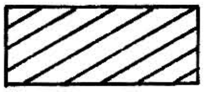


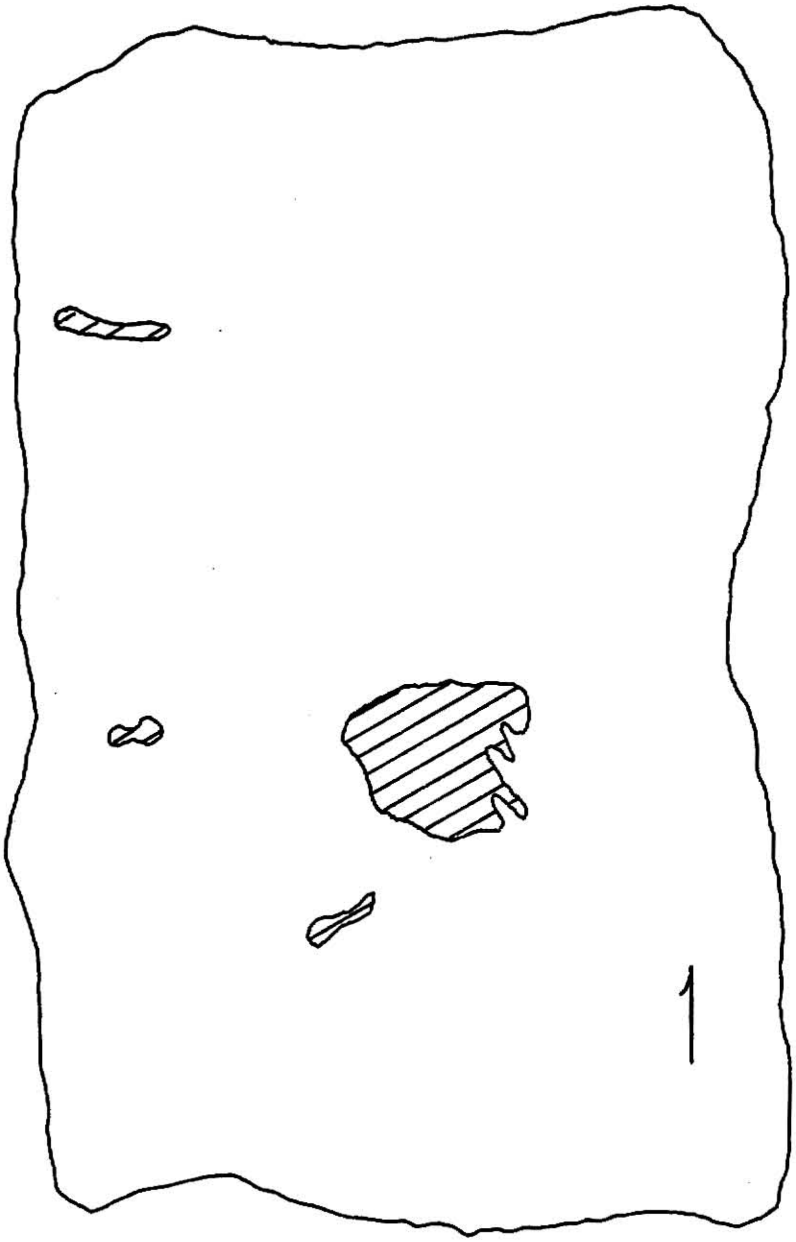
Bed: 8
Scale: Actual size.

Filled Burrow:

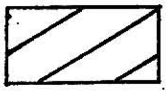


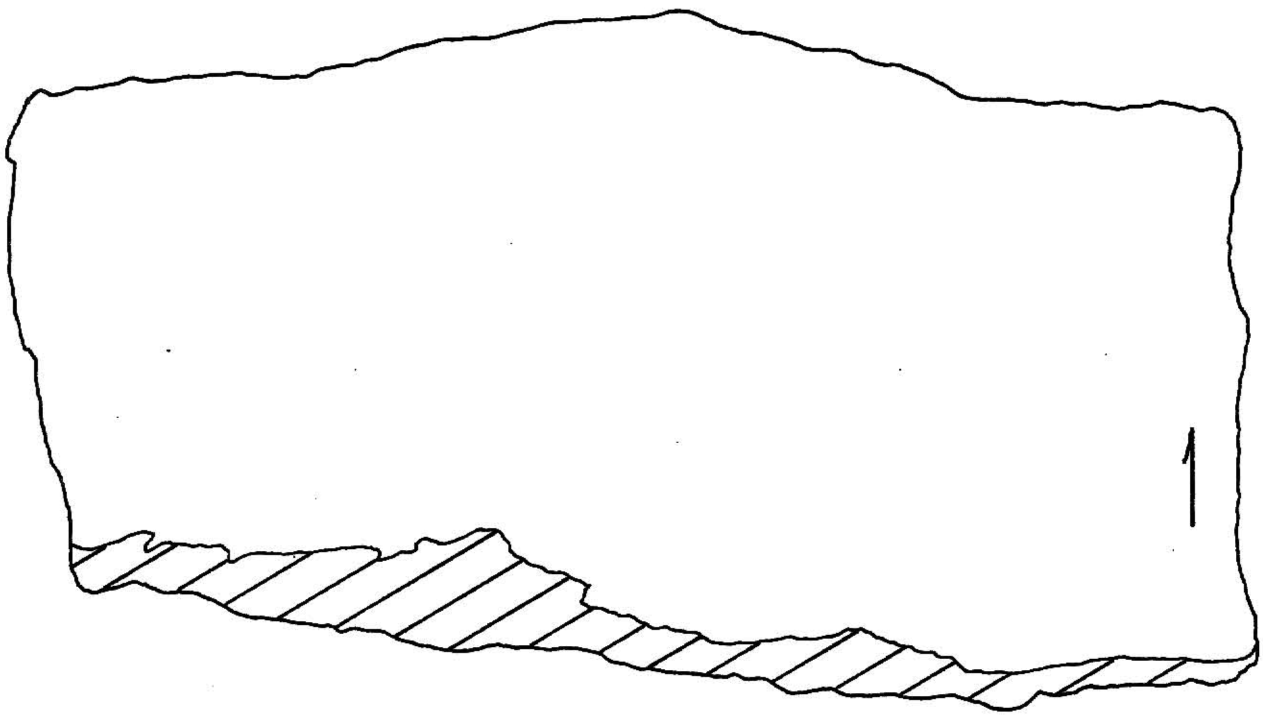
Bed: 9
Scale: Actual size.

Filled Burrow: 



Bed: 10
Scale: Actual size.

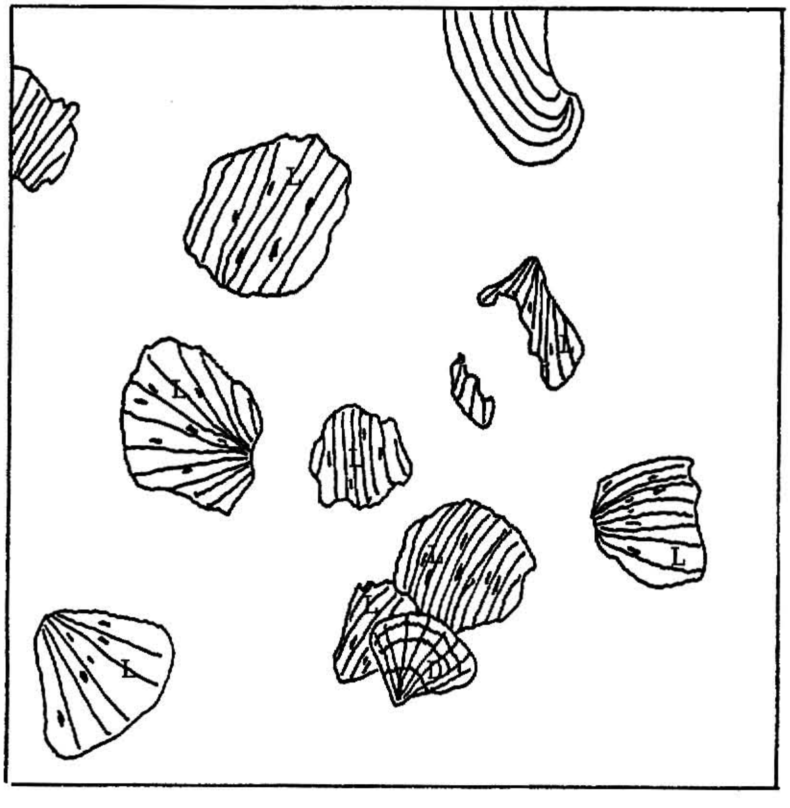
Filled Burrow: 



APPENDIX 4a

Bedding Plane Data: Biotic Spatial Distribution

Introduction.--The sketches below are of decimeter square areas of bed 4 and at the contact of beds 6 and 7. The maps are of lower surfaces, parallel to bedding.



Biota: Linoproductus sp., (L); Derbyia cf. crassa, (D).

Lithology: Carbonate midstone.

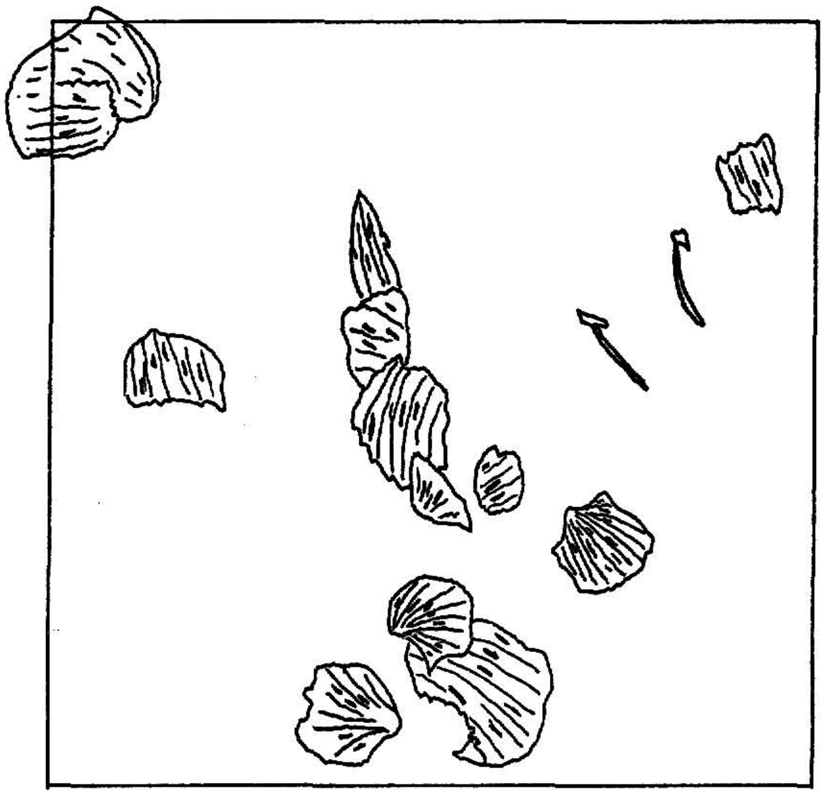
Bed: Contact of 6 and 7.

APPENDIX 4a (cont.)

Biota: Linoproductus sp. (mostly pedicle valves and some spines).

Lithology: Siltstone

Bed: 4



APPENDIX 4b

Tabulation of Bedding Plane Data

Introduction.--To get a better idea of size and composition of the assemblages, the numbers of individuals in life position and not in life position in the original collection site (site 18, fig. 5) were recorded, however later supplemented with data from Pearce (1973). Numbers in parenthesis are from my data, the others are from Pearce (1973).

	Beds					
Taxa;	10	9	8	7	6-t	4
Pteronites cf. *peracuta*	38	21(1)	20(1)	4		
Wilkingia cf. *elliptica*	36	7	38(13)	9(4)		
Echinaria cf. *moorei*	11	2	62	1		
Enteletes cf. *hemiplicatus*	23		14			
Linoproductus sp.	40	9		13	(37)LP* (12)NLP*	(72)LP* (15)NLP*
Neochonetes sp.	64					

*LP - indicates life position; NLP - indicates non-life position.

Note: With the exception of *Linoproductus* sp. all numbers are of individuals in life position per unit or bed.

APPENDIX 5

Thin Section Data: Orthochemical-Allochemical Constituents

Introduction.--Numbers represent the number of observations during a 600 point count of each bed or unit. For example, unit 10-t, of the 600 points, 64 fell on micrite, 244 on microspar, 19 on spar, 61 on pyrite, etc.

	Bed (Unit)					
Constituent:	1	2	3	5	7	8
Orthochemical						
Micrite	204	278	384	210	179	361
Microspar	192	112	72	56	170	64
Spar	26	52	22	138	84	72
Pyrite (secondary)			3			
Limonite (secondary)				12		
Terrigenous						
Quartz	24	2	16	33	62	12
Dolomite	1					
Allochemical (fossils)						
Triticites sp.						3
Globivalvulina sp.		1	5			
Opthalmid	2	13	1			
Endothyra sp.		2	3			
Ammovertella sp.			8			
Ectoproct	2	1	1			
Brachiopod fragment	53	39	16	38	20	20
Gastropod		12				4
Ditymopyge sp.						3
Bairdia sp.	3		1	2	1	
Crinoid	13	3	3		9	9
Echinoid	20	17	40	2	10	9
Osagia sp.	7	23	1			17
Algal fragment	12	23		65	54	16
Shell debris	41	22	24	44	11	5

Constituent:	Bed (Unit) 9	10-b	10-ub	10-1t	10-t
Orthochemical					
Micrite	360	56	202	262	64
Microspar	25	212	142	158	244
Spar	23	128	118	98	19
Pyrite (secondary)	4				61
Limonite (secondary)	30	27	13	5	48
Terrigenous					
Quartz				5	76
Dolomite					4
Allochemical (fossils)					
Triticites sp.			1		
Globivalvulina sp.	11	5	1	4	7
Opthalmid	2				
Ammovertella sp.			2		
Ectoproct	3	3	5	10	21
Brachiopod fragment	10	47	46	15	5
Gastropod				1	
Ditymopyge sp.	2			1	
Bairdia sp.	3	3	6	2	
Crinoid	1	30	6	3	
Echinoid	19	35	12	10	
Osagia sp.	11	4	6	2	3
Algal fragment	28	14	19	6	9
Shell debris	68	36	21	18	39

APPENDIX 6

X-Ray Diffraction Data: Quartz, Calcite and Dolomite

Bed (Unit)	Mineral	2θ (degrees)	Angstrom Units	Area Under Curve (percent)
	Quartz	26.64	3.343	31
1	Calcite	29.48	3.027	33
	Fe Dol	30.72	2.908	36
	Quartz	26.64	3.343	13
2	Calcite	29.48	3.027	81
	Fe Dol	30.74	2.906	6
	Quartz	26.64	3.343	8
3	Calcite	29.46	3.029	88
	Fe Dol	30.72	2.908	4
	Quartz	26.64	3.343	15
5	Calcite	29.46	3.029	85
	Quartz	26.64	3.343	12
7	Calcite	29.48	3.027	83
	Fe Dol	30.72	2.908	5
	Quartz	26.64	3.343	5
8	Calcite	29.52	3.025	93
	Fe Dol	30.72	2.904	2
	Quartz	26.64	3.343	18
9	Calcite	29.52	3.023	52
	Fe Dol	30.76	2.904	30
	Quartz	26.64	3.343	18
10-b	Calcite	29.50	3.025	49
	Fe Dol	30.68	2.912	33
	Quartz	26.64	3.343	5
10-ub	Calcite	29.50	3.025	88
	Fe Dol	30.68	2.912	7
	Quartz	26.64	3.343	4
10-1t	Calcite	29.52	3.023	78
	Fe Dol	30.70	2.904	18
	Quartz	26.64	3.343	22
10-t	Calcite	29.44	3.031	19
	Fe Dol	30.74	2.906	59

APPENDIX 7

Spectroscopic Analysis Data on the Reading Limestone

Element	Film No.	Bed 1	2	3	5	7	8	9	10b	10ub	101t	10t
Ca	48i, 76e	*M	M	M	M	M	M	M	M	M	M	M
Fe	22i, 52e	M	m	m	m	m	m	m	m	m	m	M
Mg	18i, 49e	M	m	m	s	m	m	m	m	s	m	M
Mn	16i, 55e	m	s	s	t	s	s	s	s	t	s	m

Note: Film numbers are those films in the Vreeland spectroscope used to identify elements present and estimate their quantities in the sample. The lower case "i" indicates an "identification" film and the lower case "e" indicates an "elimination" film.

*Semi-Quantative Measure: (ref. Oper. Inst.: Vreeland Model 6A Spectroscope, p. 12)

M = major constituent (all lines of elimination film present)

m = minor constituent (only strongest lines of elimination film present)

s = small percent (only lines of identification film present)

t = trace (only prominent lines of identification film present)

APPENDIX 8a

Insoluble Residues in Grams Per Sand-Silt-Clay Fraction

Introduction.--The size parameters for the sand, silt and clay fractions were (1) sand, 3.0 Ø - 4.0 Ø, (2) silt 8.0 Ø - 4.0 Ø and (3) clay, greater than 8.0 Ø. The sample abbrevations are coded. The capital E indicates Emporia Formation and capital A stands for Auburn Formation. A lower case letter immediately following, indicates the member, for example (e) indicates Elmont, (h) Harveyville and (r) Reading. If a number follows immediately the member abbreviation, this stands for a bed number within the member. A dash and then a lower case letter (-ub, -t) indicates a further subdivision of a bed (or member) and in this case -ub is "upper base", -t is "top", -m is "middle", -b is "base" and -lt is "lower top".

Original sample size was*20 grams, prior to treatment.

*20.000 grams

	Fraction			
Sample	Sand	Silt	Clay	Total
Ee	0.982	0.993	0.103	2.078
Ee-b	1.654	1.085	0.513	3.243
Eh-t	0.258	10.998	1.797	13.053
Eh-m	0.027	15.665	2.675	18.367
Er 10-t	0.161	4.134	0.661	4.956
Er 10-lt	0.041	1.249	0.046	1.336
Er 10-ub	0.042	0.682	0.082	0.806
Er 10-b	0.210	3.683	0.039	3.932
Er 9	0.068	3.273	0.199	3.450
Er 8	0.102	3.418	0.247	3.767

	Fraction			
Sample	Sand	Silt	Clay	Total
Er 7	o.196	3.306	0.348	3.850
Er 6-t	0.140	7.388	0.143	8.671
Er 6-m	0.098	14.439	0.872	15.409
Er 6-b	0.095	11.513	1.244	12.852
Er 5	0.123	1.199	0.247	1.569
Er 4	0.190	10.223	0.939	11.352
Er 3	0.082	2.246	0.743	3.071
Er 2	0.106	2.862	0.782	3.750
Er 1	0.150	5.135	0.955	6.240
A-t	0.133	8.276	1.414	9.823
A-ub	0.014	9.654	4.860	14.528
A-b	0.013	13.196	0.937	14.146

APPENDIX 8b

Insoluble Residue Grain Mineralogy and Morphology

Introduction.--The petrologic examination was limited to fifty grains of the sand fraction (3.0 Ø to 4.0 Ø). Unit abbrevations are the same as used in Appendix 8a. Abbrevations used in the ROUNDNESS column are: (1) A = angular (2) SA = sub angular, (3) SR = sub rounded and (4) R = rounded. In the INCLUSIONS column, BT'S = bubble trains, Z = zircon, T = tourmaline and MC = microlites. Not every grain possess inclusions, therefore this column will not reflect fifty points total. One exception exists to the fifty grain count and that is unit Er 10-b, in which 70 grains were counted.

To read the forms, an example may be given on unit Ee (Emporia Formation, Elmont Limestone Member). For example, two feldspar grains were counted; one was between 2.0 Ø and 2.25 Ø and the other was between 2.5 Ø and 2.75 Ø size. Both grains had a low sphericity and were angular.

UNIT: A-b	SIZE (PHI UNITS)																SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL	4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common			1																1		1			1			
Quartz, micro (chert)					3	2		3	3	1							10		2		2	9	1		6		4
Quartz, mega					5	7	5	4	6	4	3	1	1				23	3	10	4	27	4	1		5	2	9
Pyrite				1															1			1					

UNIT: A-ub	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL		4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common				2	3	5	4	1										11	1	3	4	10	1		5	3		8
Quartz, micro (chert)		1		1	5	2	1											7	1	2	1	5	4					
Quartz, mega				1	1	3	2	1										4	1	3	1	5	2					1
Oligoclase						1														1			1					
Microcline					1															1			1					
Pyrite				1	1		1												1	2	1		2					
Limonite						1		1										2					2					
Muscovite					1	3	4	2										7		3	2	2	4	2				

UNIT: A-t	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL	4				3				2				1				0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common				2	7	4	1											2	2	10	6	6	2		7			5
Quartz, micro (chert)						2	3	2	2	2			1	1				12	1		2	8	3					
Quartz, mega				1	1	1	4	1	1	2								8	1	2	9	2				2	1	3
Pyrite				2	2				1		1							4		2	2	4						
Muscovite										2			1						1	2			2	1		1		
Celestite											1								1					1				
Zircon		2																1		1	2							

UNIT:Er 1	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL		4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common		1		5	4	4	2											11		5	3	11	2		2			4
Quartz, micro (chert)		1	1	2	3	2	5	2	1	1	1			1				15	1	4	10	9	1			1		12
Quartz, mega				3	4		2											5		4	3	3	3					3
Oligoclase				1				1										2			1	1						
Muscovite					1													1			1							
Celestite									2									2			2							

UNIT:Er 2	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL		4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common		1		3	5	1	1	2										4	5	4	7	1	4	1	8	2		7
Quartz, micro (chert)		1				2	2	3	3	2	3	3	4	1	1			19	7	2	9	16	3			2		18
Quartz, stretched metamorphic						1												1				1						
Pyrite				1			2												1	2	1	2						
Limonite						1			1									2					1	1				
Muscovite					1			1										1		1				2				1
Celestite										1								1			1							

UNIT: Er 3	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL		4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common			1		3	2	5		1									10		2	3	7	2		3	1		6
Quartz, micro (chert)				5	1	6	3	2	1	2				1				16		5	15	6						4
Quartz, mega				2	2	3	2	1										7		3	3	4	3			1		2
Pyrite							2				1							1		2		3						
Muscovite						1														1	1							
Celestite							1						1			1		3			1	2						

UNIT: Er 4	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL	4				3				2				1				0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common			1		2		1	2	1									4		3	2	3	2		1	1		2
Quartz, micro (chert)				2	3	2	5	6	1	3		1	3					19	1	6	7	19				2		6
Quartz, mega			1	2		2	3	3	1									7		5	2	9	1			2		6
Pyrite					1		1											1		1		1	1					
Limonite								1										1			1							
Muscovite							2											2			1			1				

UNIT: Er 5	SIZE (PHI UNITS)																SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL	4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common			2	3	2	3	3	1									6	1	7	6	4	3	1	4	2		11
Quartz, micro (chert)	1	1	1	4	5	4	6	3				1	1				21		6	12	15						4
Quartz, mega				1	1		2	1		1							5		1	1	3	2					
Oligoclase					1														1			1					
Celestite									1		1						2			1	1						

UNIT: Er 6-b	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL		4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common			1	6	10	5	1	1										12	2	10	8	10	6		9			10
Quartz, micro (chert)				1	1				1										1	2		3						1
Quartz, mega				3	8	3	1											7	1	7	2	9	4					
Quartz, stretched metamorphic			1															1			1							
Pyrite			2	1	1													1		3		2	1	1				
Limonite		1																1					1					
Muscovite						1														1			1					
SRF						1														1		1						

UNIT: Er 6-m	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL		4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common			3	3		2		2	1									7	1	3	1	6	4		2	7		7
Quartz, micro (chert)				2	1		2											1	1	3		1	4					
Quartz, mega		1	2	3	1	2	2											6	2	3		10	1					
Quartz, vein				2	1													2		1		3						
Pyrite						3													1	2		1	2					
Limonite				1		1			1									1	1	1		1	2					
Muscovite				2	2		5	2										6		5		1	3	7				1
Biotite					1		1	1										2		1			1	2				

UNIT: Er 6-t	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL		4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common		1	1	8	9	5	3	1										18		10	17	9	2		4	5		17
Quartz, micro (chert)		1		3														1		3		1	3			1		1
Quartz, mega					2	2	2	1										4		3	3	4			2			5
Quartz, vein				1	3	1	1											4	1	1	2	4						
Feldspar, oligoclase					2			1										1		2	3							
Microcline							1											1				1						
Pyrite					1	(euhedral)														1	1							

UNIT: Er 7	SIZE (PHI UNITS)																SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL	4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common			4	9	8	2	2	4									13	5	11	6	7	13	3	13	4		12
Quartz, micro (chert)			1		2			1										2	2		1	2	1		2		2
Quartz, mega				4	1	1	1	1									4		4	1	4	3			1		4
Quartz, chalcedonic						1											1					1					
Feldspar						1											1			1					1		1
Muscovite							1	5	1								4	2	1			3	4				1

UNIT:Er 8	SIZE (PHI UNITS)																SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL	4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common	2	1	2	6		5		1									11	2	4	8	7	2		2	2	2	9
Quartz, micro (chert)	2		5	1	1	3	4	3	2	1	1	1	1	3			24	2	2	21	5	2			3		7
Quartz, vein			1	1														1	1	1		1					2
Quartz, stretched metamorphic							1										1			1							1
Muscovite				1					1										2				2				

UNIT: Er 9	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL		4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common				4	6	3	7	2										14	2	6	17	5			9		1	13
Quartz, micro (chert)		?		2	4	5	2	2	1	2								10	2	8	14	6						2
Quartz, mega					1															1	1							
Quartz, stretched metamorphic						2												2			1	1						
Pyrite				1																1		1						
Muscovite					1				1									1		1	1	1						
Celestite						1	1											2			2							

UNIT: Er 10-b	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL		4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common					2	1												2		1	2	1			1	1		2
Quartz, micro (chert)		1	1	7	10	3	6	9	3	3	1		1					34		11	29	15	1					14
Pyrite						1	1	2		1	1							3		3	4	2						
Muscovite							1											1			1							
Collophane												1	1							2	1	1						
Celestite					1		2	4		1	1		1		1	1		7	4	1	7	5						
Corundum											1							1			1							

UNIT: Er 10-ub	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL	4					3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, micro (chert)		2		2	3	1	8	8	3	1	2		2				1	24		9	16	17						13
Pyrite			1				1	1	1									3		1	2	1	1					
Limonite				3	2	2	2	3		1								12		1	3	8	2					

UNIT: Er 10-1t	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL		4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common					2		2	2										2		4	4	2						2
Quartz, micro (chert)		1	1	2	3	2	5	6	2	1	1	1		1				16	2	8	13	13				2		14
Limonite		2			3		5											3		7	5	3	2					
Pyrite		2		3	2		1											2	1	5	6	2						

UNIT: Er 10-t	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL		4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common					2				1									2		1	1	1	1		2			2
Quartz, micro (chert)		1		2	2	2	5	7	1	7	1	4						24	1	7	20	12				1		31
Quartz, stretched metamorphic								1										1			1						1	1
Pyrite				1		1	3	3										3		5	6	2						
Limonite								2	1									3			3							
Collophane				1	1						1							2		1	1		2					

UNIT: Eh-m	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL		4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common						1	1		1									3			1	2					2	3
Quartz, micro (chert)				1	4	7	10	2	7	4	1	1						18	2	17		16	16	5			1	2
Quartz, mega							1													1			1					
Quartz, stretched metamorphic								1										1			1							
Quartz, chalcedonic							1	1		1								3					3					
Feldspar									3									2		1			2	1				
Muscovite						1														1		1					1	
Magnetite					1													1						1				

UNIT: Eh-t	SIZE (PHI UNITS)																SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL	4				3				2				1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common		1	5	8	3	4	5		2								17	4	7	9	9	9	1	12	2		15
Quartz, micro (chert)					1	3	2				1			1			7		1		4	4					
Quartz, mega		1	1	1		2											3		2		4		1				
Quartz, stretched metamorphic				1			1										1		1		1	1			2		
Feldspar					1		1										1	1				2					
Muscovite				1		2	1	1									2		3		3	2					

UNIT: Ee-b	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL	4					3			2					1			0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common			2	2	3	4	7	6										15	4	5	11	9	4		3	7		7
Quartz, micro (chert)				1	1	1	1	1	2									3	2	2		3	3	1				2
Quartz, mega									1									1				1						
Quartz, vein				1	4	1	2	3										8	1	2	3	6	2					1
Muscovite							1		1			1						1		2	3							
Orthoclase						1		1										2				1		1				
Microcline							1													1		1						
Limonite			1																	1			1					

UNIT: Ee	SIZE (PHI UNITS)																	SPHERICITY			ROUNDNESS				INCLUSION			
MINERAL	4					3			2				1				0	LOW	MED	HI	A	SA	SR	R	BT'S	Z	T	MC
Quartz, common		1		1	1	5	5	5	2							1		17	3	1	15	5	1		6	3		
Quartz, micro (chert)			1		1		3	1	3	1	1	1						11	1		4	3	5					
Quartz, mega								2										2				2				2		
Quartz, vein				2		3	1	2	1					1				6	2	2	4	6						
Feldspar							1		1									2			2							
Tourmaline		1	(euhedral)															1				1						
Limonite								1										1					1					
Muscovite										1								1					1					

MARINE BENTHIC COMMUNITIES OF THE READING LIMESTONE (UPPER PENNSYLVANIAN) ATCHISON COUNTY, KANSAS

by

DAVID RAY SCOTT

B. A., Kansas State University, 1964

AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

Fossil assemblages of a thin interval of the Upper Pennsylvanian Emporia Formation (Reading Limestone Member), at one locality, have been shown to be contributors to three successive marine benthic communities. Criteria for determining life assemblages were position of fossil with respect to enclosing lithology, size frequency distributions, condition of preservation and grain size. Stratigraphically, from oldest (lowest) to youngest (highest), the communities are *Neochonetes* of the lower limestone, *Linoproductus* of the middle siltstone and *Wilkingia*-*Pteronites* of the upper limestone.

Structure of these communities was based on the trophic group concept developed by Turpaeva (1957). Using this concept the community structure was inferred to remain the same throughout the Reading Limestone, although different taxa are substituted or replaced within the structure.

Environmental changes, reflected by lithologic differences, correspond to community changes. Insoluble residues, x-ray diffraction and thin sections were used to establish lithologic differences. Terrigenous influx, appears to have had the greatest influence on taxa substitution within community structure.

The Reading Limestone was deposited on an embayed shelf or in a shallow lagoon. Differences in the ratio of terrigenous influx to carbonate sedimentation are responsible for environmental differences.