ENVIRONMENT OF DEPOSITION OF THE BRASSFIELD FORMATION

Asenior thesis submitted in partial fulfillment for the degree
of Bachelor of Science
at
The Ohio State University
Department of Geology and Mineralogy

by

William Allan Clapper, Jr.

advisor: Kenneth Stanley

TABLE OF CONTENTS

MAPS

LIST OF ILLUSTRATIONS

INTRODUCTION

This study is an examination of the Brassfield limestone at the Hihgland Stone Plant Quarry near Hillsboro in Highland County, Ohio.The purpose was a petrographic examination of a typical section of the Brassfield Formation in order to determine the environment of deposition and ultimatly to determine the depositional history of the formation.

Previous Work

The Brassfield Formation has been studied at least since before 1838 by Owen in Indiana. It was originally correlated with the Clinton of New York by Orton (1871), based on stratigraphy and lithology rather than on faunal evidence. Due to differences in fauna, Foerst (1896) proposed a land barrier between the two and proposed the name Montgomery limestone for the typical development in Montgomery County, Ohio. The name lapsed, and in 1906 he renamed the Clinton beds in Kentucky the Brassfield, and three years later he did the same for the Clinton age beds in Ohio.

Unpublished petrographic studies of the Brassfield were done by Fennel in 1952 and Hopkins in 1954, which consisted of insoluble residues and thin sections to determine mineral distribution.

Map 1. State of Ohio showing the location of Highland County

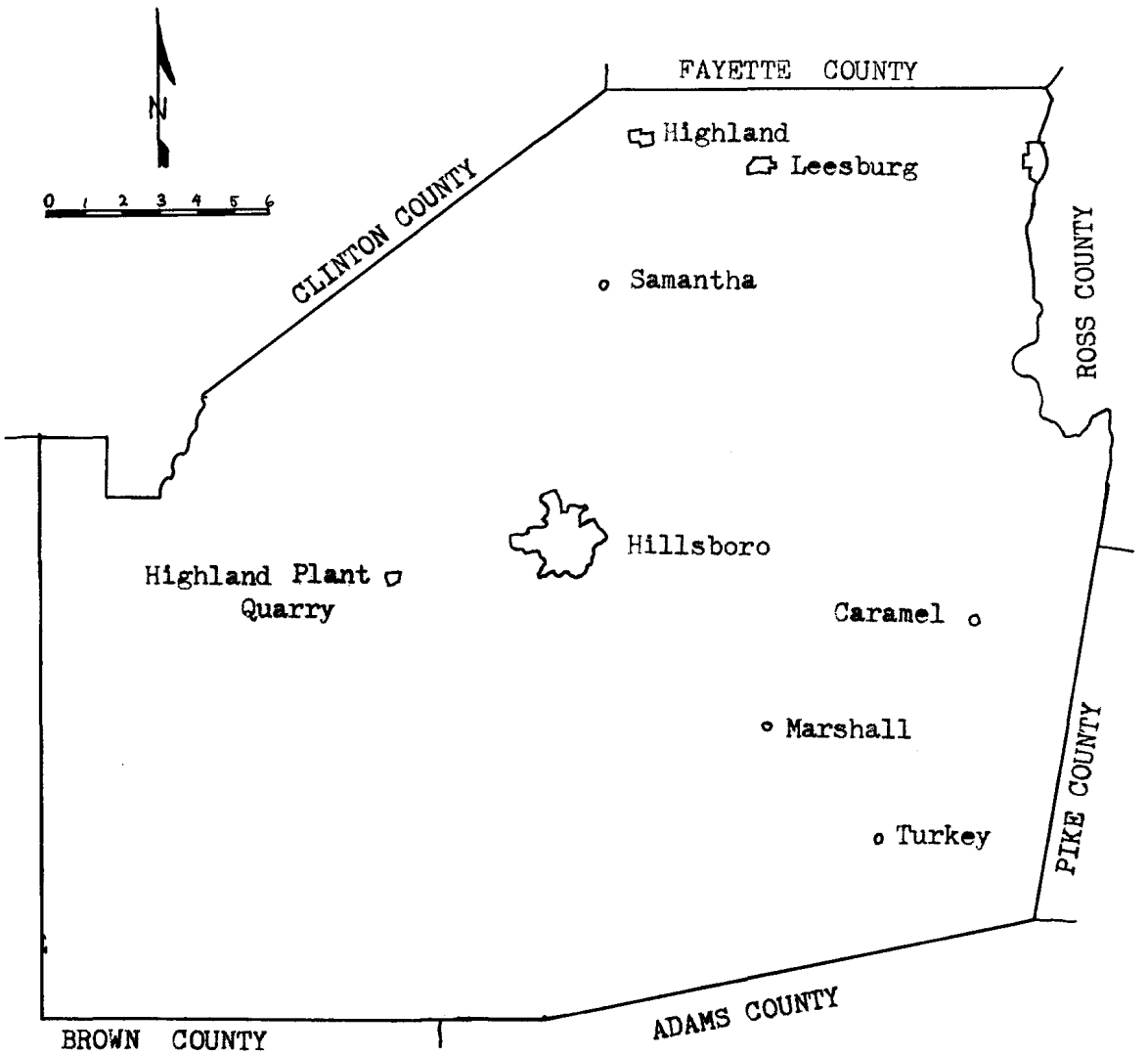
The Brassfield limestone is a very well spread out deposit extending as far as western New York, southern Ontario, Alabama, Tennessee, Indiana, Illinois and Ohio, and has been reported as far west as Oklahoma and Arkansas (Hopkins,1954). The type locality has been described for an outcrop along the Louisville and Atlantic Railsoad between Panola and Brassfield in Madiso County, Kentucky. The Brassfield has been described by Foerst (1906) as follows:

> The lower part of the Brassfield limestone usually consists of one or several rather thick and massive appearing layers, while the middle and upper parts consist of more numerous, thinner bedded layers; toward the top of the section these limestones often are interbedded with thin layers of clay.
>
> The massive layers at the base, usually are unfossiliferous. They do not weather to a deep rusty-yellowis-brown as the thinner layers of the Brassfield limestone. Frequently they have a more argillaceous appearance than the thinner layers, and their color, when freshly exposed, is more bluish.
>
> The overlying parts of the Brassfield limestone are too thin bedded and irregular to be of value for any purpose except crushed rock. In the lower part of this thin bedded section, the limestone layers are likely to be separated by thin layers of clay. In the upper part of the Brassfield section, these layers of clay are likely to be thicker, but not sufficiently to predominate over the limestones. It is the upper thinner part of the Brassfieldlimestone which is fossiliferous. Most of the fossils occur near the top of the section.

At the investigation site, the Brassfield is marked by an unconformity at both the top and bottom. This makes the Brassfield an isolated single transgression and regression of a sea, and is one of the reasons this formation was selected for investigation.

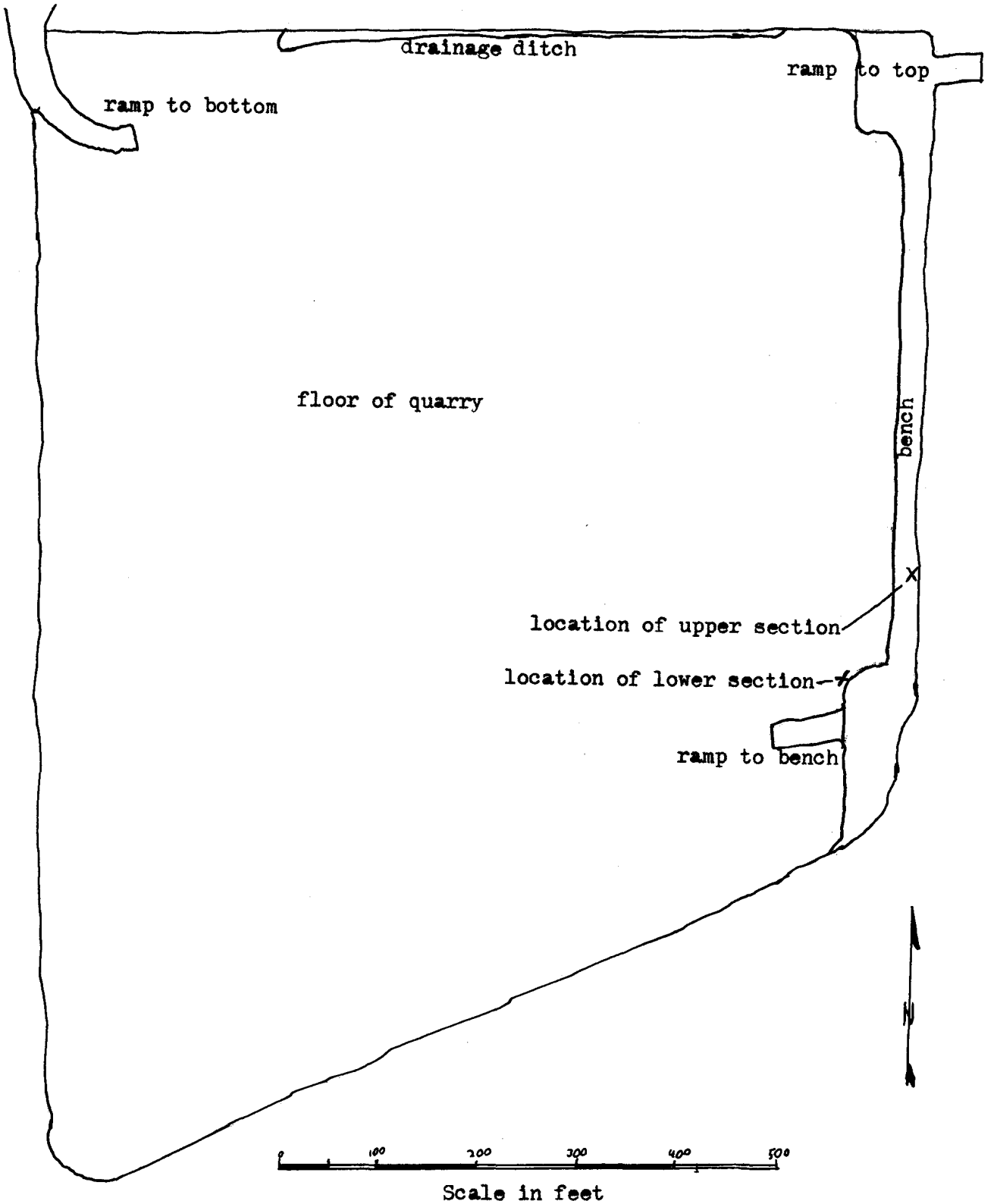
INVESTIGATION

The brassfield Formation is readily divisible into two major units, both lithologically and economically, at this site. Only the lower twenty to twenty five feet can be profitably quarried, containing only two to four percent shale. The upper seven to eight feet contain up to forty percent clay, which cannot be removed profitably (Bowman, personal communication). The lower unit starts out immediatly on top of an unconformity above the Elkhorn shale in the form of a massive light gray limestone, indicating a very rapidly transgressing sea which began depositing carbonates immediatly. The rock is at first a very fine grained clastic limestone, indicating a near shore environment, and very quickly grades into a coarser material, more typical of quieter and deeper water. At this point the beds begin to take on a very undulatory, almost a rolling, shape. The undulations are too random and irregular to be classed as true ripple marks, but a wave effect is apparent. A surface made by these undulations would greatly resemble the bottom of large bodies of fairly quiet water below the normal wave effect but still capable of being sculpted by large storm waves coming from several directions at once. I have seen this type of bottom in Lake Erie away from the shore many times at a depth of thirty to fifty feet. The bottom was at this time too turbid to most forms of life, as evidenced by a notable lack of fossils.



Map 2. Highland County showing location of Highland Plant Quarry

Map 3. Highland Plant Quarry showing location of measured sections. Scale: one inch equals 150 feet



As the basin filled, higher energy in the water due to less depth allowed the water to clear somewhat, and bryozoans took hold. This occurs about eight feet up from the bottom of the section and is marked by the appearance of isolated bryozoans and a change in the rock lithology, from an almost crystalline texture to a coarser clastic one containing many very small fossil fragments. The boundary is marked by a layer of shale two to three inches thick, possibly representing a short period of a local closed or semi-closed lagoon before becoming open to the sea again. This sequence is also marked by cross bedding and local thin shale lenses indicating alternating periods of high and low energy. From here on, shale becomes more and more common in the form of partings between beds of limestone.

The next two feet up herald a return to quiet water. The beds become smoother and clastic particles become smaller and contain more crystalline cement. Bryozoans die out but numerous worm burrows appear, often filled with pyrite. This is indicative of of stagnant water with under moderate reducing conditions. These beds also contain chert nodules of undetermined origin and darker lamelli which again indicate a reducing environment. The lighter portion of the laminations may indicate that some water was exchanged. Immediatly above this unit is a ahale layer about one inch thick.

The next unit is a limestone layer similar to the previous one but without the chert or pyrite. It contains more

Photo 1.
Overall view of quarry with location of lower (a) and upper (b) measured sections and limits of fig. 1 (c,c').

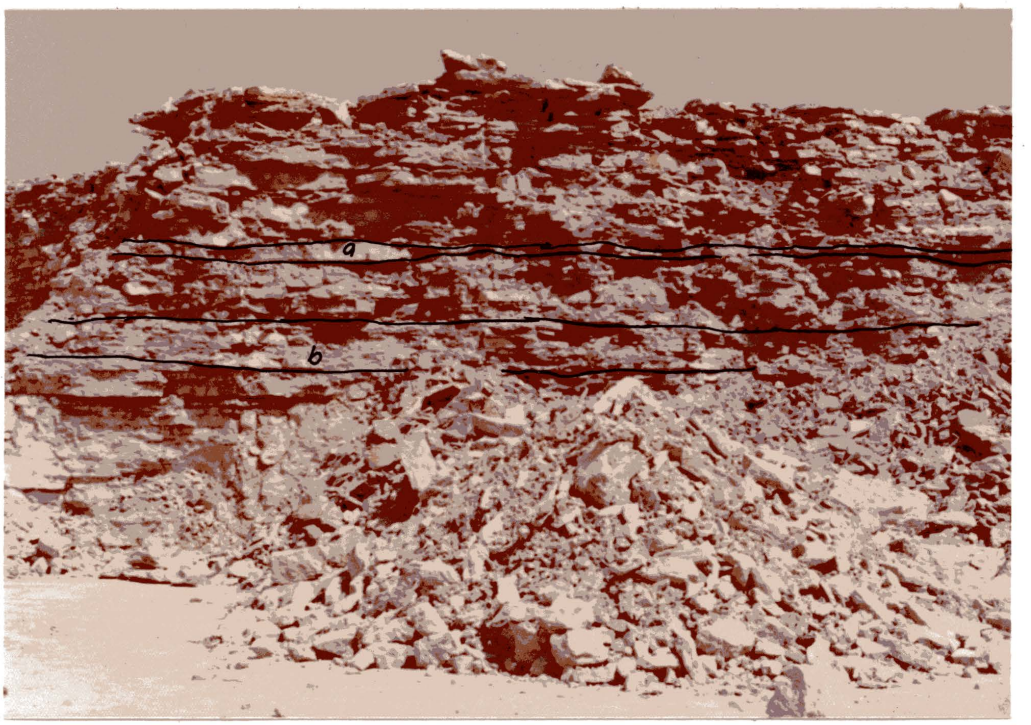


Photo 2.
View of lower measured section with sandstone (a) and major chert bed (b) outlined. Note undulation of beds near top.

Map 4. Areal extent of Brassfield Formation. Western boundary has not been determined or correlated, modified from Rogers.

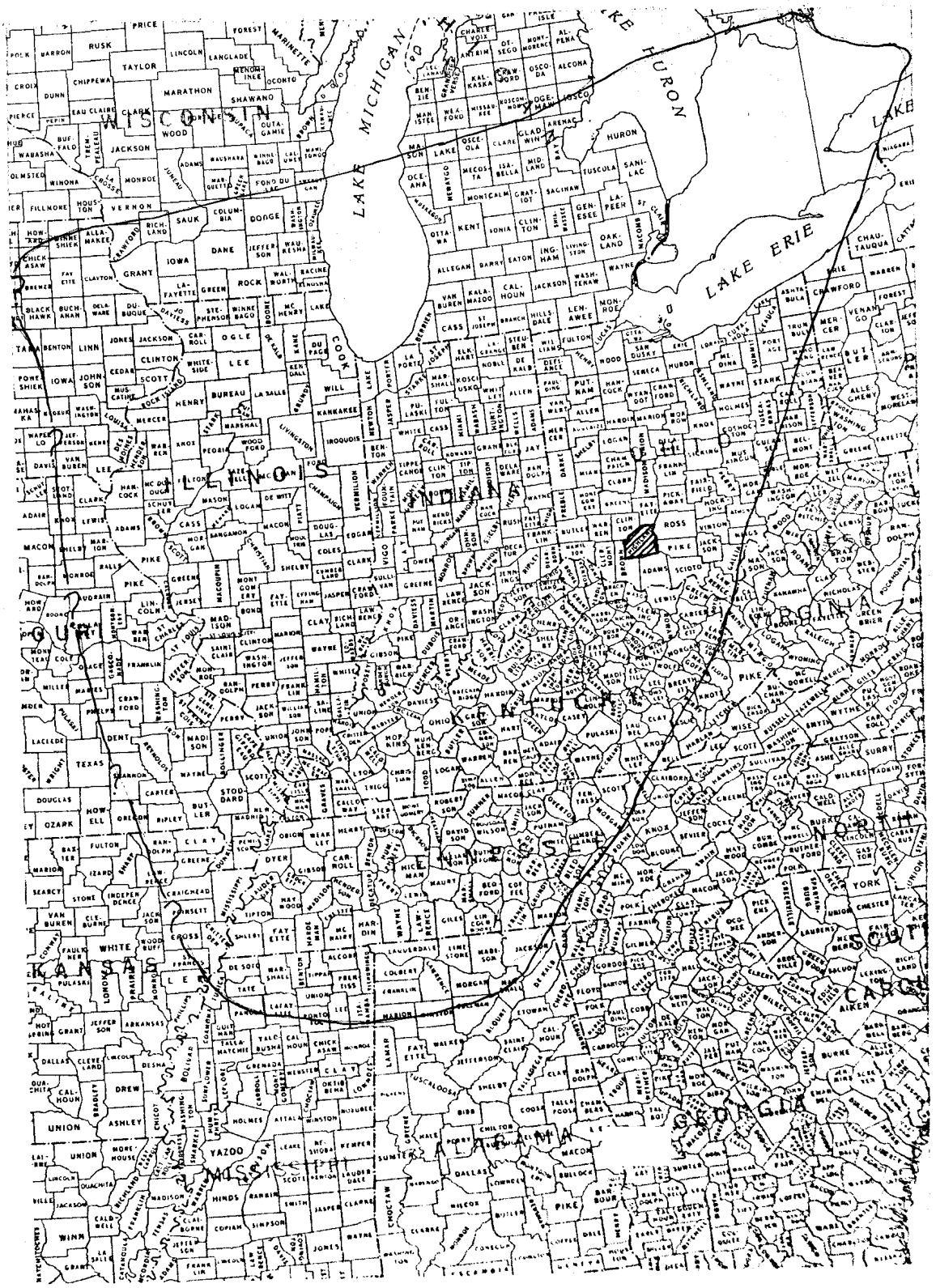


Figure 1. Drawing of East wall of quarry. Scale: one inch equals sixty feet, vertical exaggeration ten to one.

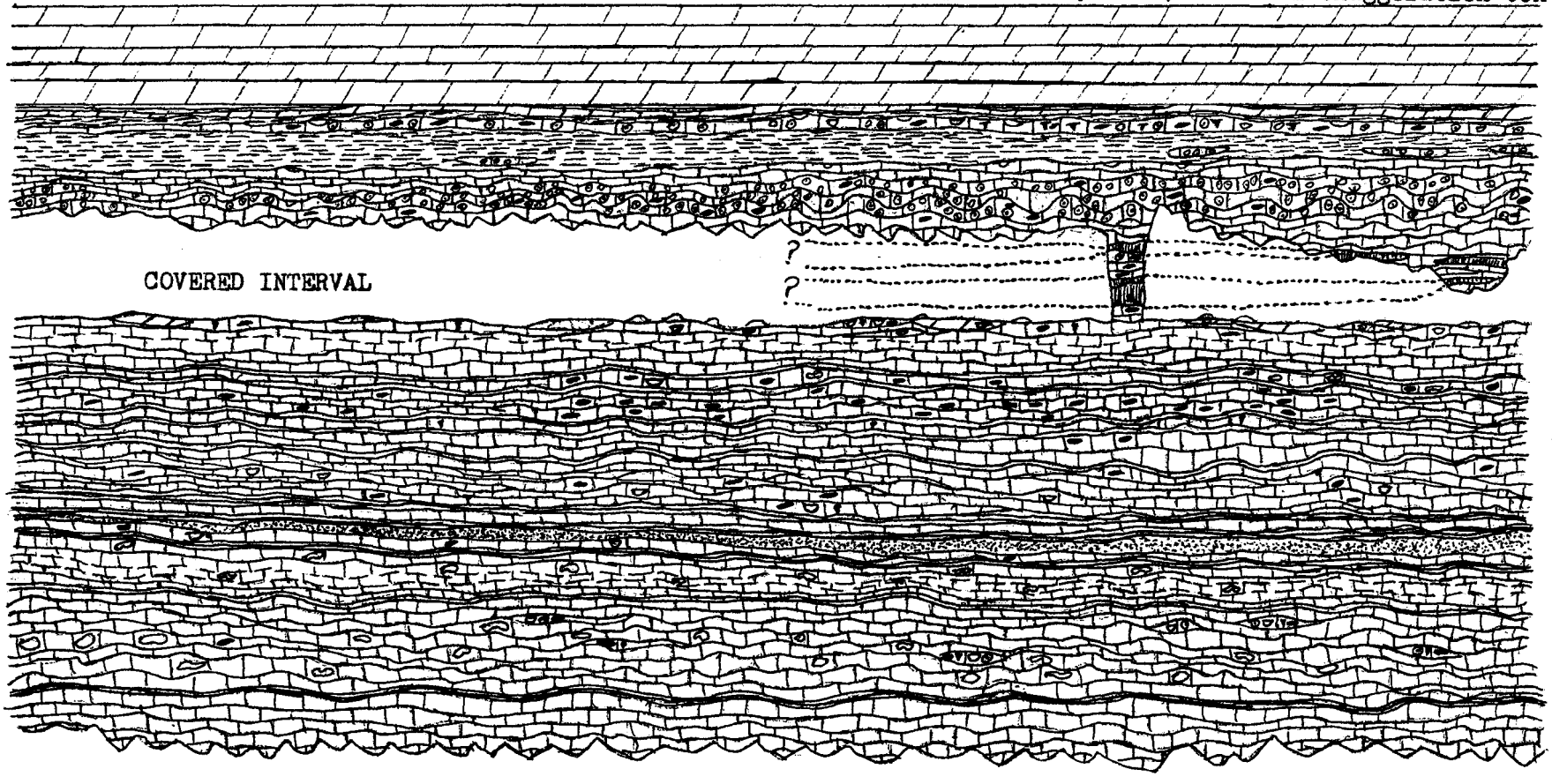
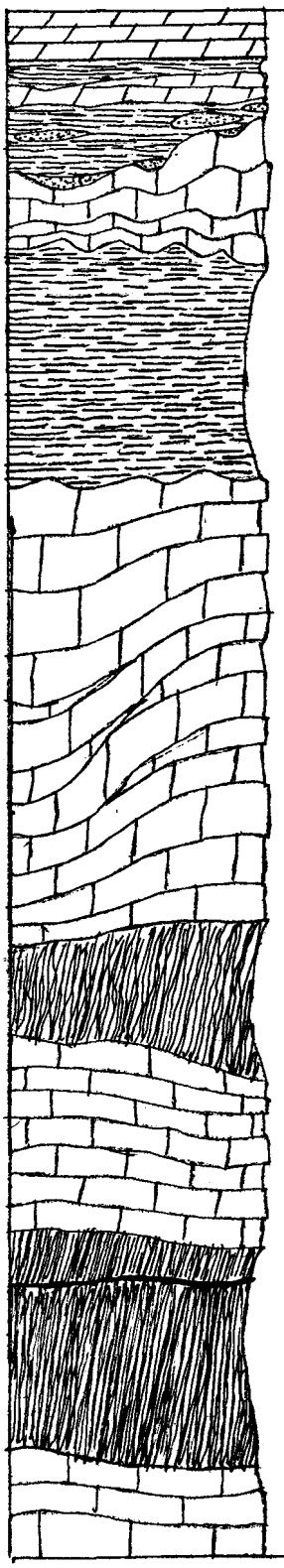


Figure 2, Stratigraphic column of upper bench taken about 125 feet North of ramp on East wall. Scale: one inch equals one foot



Dolomite of Dayton Formation
Shaley siltstone, greenish gray, fractile
Dolomitic limestone, buff to gray, fine grained
Shaley siltstone, light gray with bluish tint, thin sharplycurved beds, sandy lenses
Limestone, medium gray to yellow to brown, some mud cracks, channels cut into top

Siltstone, medium gray with green near top, and yellow near bottom, friable, chunky, thin beds

Limestone, medium to dark gray near top to red near bottom, coarse clastic matrix supported grains, beds very undulatory with some cross bedding, abundant fossil fragments

Silty clay, mediumgray with greenish tint, beds to $\frac{1}{4}$ inch, soft

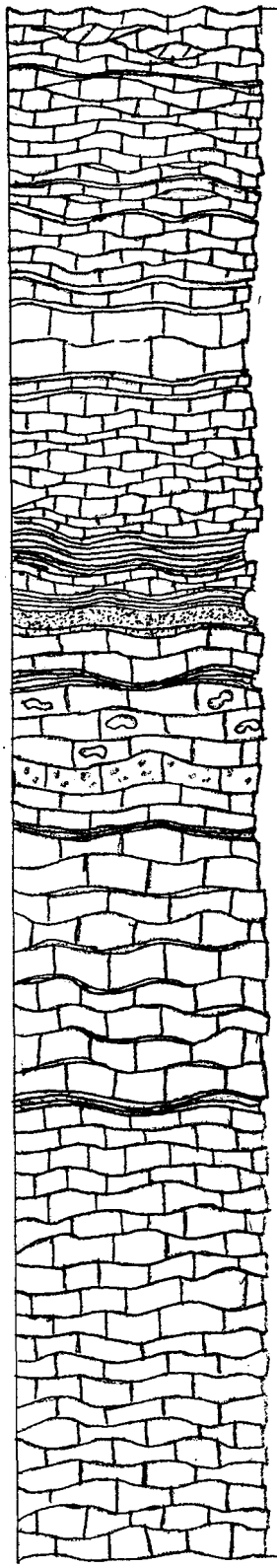
Limestone, light gray, small even grains, beds one to four inches, no fossils

Clay mud, yellow brown, viscous liquid

Silty clay, medium gray with green near top, friable, soft

Limestone, light gray, small even grains, beds one to four inches, few fossils

Figure3. Stratigraphic column from bench to floor of quarry, taken fifty feet north of ramp. Scale: three-eighths inch equals one foot.



Limestone, light gray, medium to coarse grained, lenses of fossil fragments, dolomite, shale
Shale, medium gray, very thin bedded, fractile
Limestone, medium to light gray, medium grained, uneven bedding, no fossils, shale lenses
Shale, medium gray, very thin bedded, fractile
Limestone, light gray, medium grained, bryozoans
Shale, medium gray, very thin bedded, fractile
Limestone, light gray, medium grained, burrows
Shale, medium gray, very thin bedded, fractile
Limeston, medium gray, medium grained, laminated
Shale, medium gray, very thin bedded, fractile
Silty limestone, medium gray, less silt at bottom
Shale, medium gray, very thin bedded, fractile
Silty limestone, medium gray, fine grained
Shale, fine grained, very thin bedded, fractile

Limestone, medium to light gray, medium grained, uneven bedding, shale partings, bryozoans

Muddy shale, light gray, very thin bedded, clay
Limestone, light gray, medium grained, silty
Muddy shale, light gray, very thin bedded
Sandy siltstone, light gray, limey to bottom
Silty limestone, medium gray, isolated fossils
Shale, medium gray, very thin bedded, fractile
Limestone, medium gray, fine grained, some darker lamelli, some chert nodules, some beds of abundant pyrite, shale partings

Shale, medium gray, medium grained, fractile

Limestone, medium gray, medium grained, rippled beds, shale partings, lensed of abundant fossils

Clayey shale, dark gray with green, clumpy, wet

Limestone, medium gray, medium grained, uneven bedding, possible algal mats, some darker laminations

clastic fragments and broken fossil debris, which means the area was again open to the sea. This limestone grades upward into a very fine sandstone through a series of very fine interbeddings (photo 17). This sandstone is distinctly laminated and tends to break along these laminations. The sandstone is very well sorted with a calcareous cement. This layer does not undulate like the rest. The sandstone bed seems to indcate a quiet, near shore environment, possibly in deeper water. The sandstone grades upward into a siltstone and then into a shale bed about two to three inches thick. There is a two inch bed of clastic limestone and another bed of muddy shale about six inches thick above this.

From here until the top of the lower section, all limestone beds are very undulatory in nature with many thin shale partings following these undulations. All the shale partings and beds from here up are of a very even thickness, as if a turbid cloud were injected into the water and allowed to settle.

The next limestone layer is a thin bedded, undulatory, clastic limestone with some cross bedding. It is the first unit which might be termed moderatly to abundantly fossiliferous, containing bryozoans and many broken braciopod shells. The cross bedding indicates a current, possibly fresh water, which would explain the lack of corals in what appears to be an otherwise ideal environment. Laminations in this bed are apparently due to differences in particle size (photo1).

Next comes a layer of limestone similar to the preceding unit in between two half inch layers of shale. The limestone can probably be traced laterally to the layer below, likewise, the two shale layers are probably two different tongues of the same unit

The next bed is a fairly massive limestone bed with a large number of silt filled burrows and a discontinuous shale parting about halfway through. The bed is faintly laminated with the darker laminations being finer (photo 19). It is interesting to note that the shale parting occurs only in the hollow parts of the undulations, indicating the possibility of a slight current keeping the high spots relativly clean. As this limestone is slightly silty and fossils are very sparse, the water was probably too turbid to support most forms of marine life.

After a half inch of shale comes another limestone bed about two to four inches. This limestone marks the first appearance of corals. The limestone is clastic, slightly marked by darker lamelli, and composed of broken fossil fragments. The material is slightly coarser at the bottom and grades finer upward. At the top of this unit is a coral attached to the limestone but growing upward into the overlying shale deposit. During this time, the energy of the environment was slowly decreasing, and eventually became turbid, killing off most forms of life, especially the corals.

The next bed to be deposited was another clastic bed, abundantly fossiliferous, containing examples of practically

Photo 3.
Sandstone bed in lower section. Centimeter scale shown.

Photo 4
Chert nodule in chert bed of lower section. Centimeter scale shown.

Photo 5.
Large bryozoan from slab near top of lower section. Centimeter scale shown.

Photo 6.
Numerous worm trails on slab from about five feet from top of lower section. Centimeter scale shown.

every marine invertebrate phyla. The beds in this unit vary from one to five inches, and undulate randomly. The beds are often separated by very thin shale partings, although there is no silt mixed with the limestone itself. This would seem to indicate a moderate to low energy environment ideal for a large variety of organisms periodicly invaded by turbid water.

At the top of this unit is about half an inch of shale followed by two to six inches of clastic limestone some bryozoans and thin shale lenses. This probably means a return to more turbid water. After a half inch of shale comes another bed of similar limestone almost twenty inches thick. The shale layer between the two probably thins out and disappears laterally, as the two limestone beds are almost identical. The thin shale lenses disappear toward the top.

The top bed of the lower section is a medium to coarse grain clast limestone containing many broken fossil fragments. This bed is distinctly lensy, containing lenses of dolomized limestone and separate lenses of very abundant fossils. Again, nearly every marine invertebrate phyla is represented. The top of this unit contains distinct ripple marks(photo 10). Similar ripple marks are found in this unit over a wide area of the Brassfield. These are reported by Hopkins (1954) and Rogers (1936), who says:

> Large ripples, called "para ripples" by Bucher are common in the Brassfield formation. Although of somewhat more frequent occurance in the upper hematitic layers, they also occur in the lower part,

> which is generally more thinly and evenly bedded. In wave length, they range from one to two feet, and in amplitude up to two inches.

The ripples here are less distinct than those found elsewhere, probably due to deeper water.

The upper section is more interesting litologically, as it contains a wide variety of rock forms. Due to the large amount of clay and shale, this part of the Brassfield is not used commercially.

The lowest unit of the upper section is a fine grained clastic limestone, without fossils, very similar to the unfossiliferous layers in the upper part of the lower section. This probably represents a lime mud similar to that found today in the Bahama Bank. After this came an invasion of turbid water which deposited nearly ten inches of silty clay. This water was extremly quiet and stagnant, as evidenced by a green reduction color. The area probably became open again since on top of this there is a layer of yellow clay, the same color as iron hydroxides such as limonite.

On top of this clay unit is a ferrunginous limestone unit about two and a half feet thick. This limestone is composed mostly of rounded echinoid fragments and pieces of bryozoans. All pices are well rounded to the point where many previous investgators have called the oolites. However, there is no evedence of layering to the fragments, (photo 21). The bedding is very undulatory with some cross bedding, possibly due to channeling(photo 12). This seems

to indicate some sort of carbonate beach or deltaic deposit. The ferruginous layer is composed of hematite which apparently seeped into the unit from above. There is such a high percentage of hematite that it was at one time mined for the production of iron.

Next comes a bed of shaley siltstone about fifteen inches thick. This represents a return to a closed or semi-closed environment. It starts off with red and yellowish beds near the bottom, and grades to greenish near the top. Above the siltstone is three to nine inches of limestone colored from yellow through red to black. The presence of mud cracks in the rock indicates it must have been dry at one time at least and probably means that this was probably a mud flat with many changes between an oxidizing and reducing reducing environment. The top of this unit is rippled and channeled, indicating a return to an underwater environment and local small streams (photos 13, 15).

The final deposits of the Brassfield are mostly shale with a thin bed of well dolomized limestone near the top. This unit totals up to nine inches. Near the bottom are sand lenses up to three inches thick. Channels are cut into the limestone and these are filled with sand. The shale itself is cross bedded with beds sharply curved. This is indicative of another deltaic deposit. The basin appears to have been filled in at this point. The overlying Dayton dolomite is unconformable. If the basin had been filled in at this point, the unconformity would represent subareal erosion.

Photo 7.
Mud cracks on slab near top of lower section. Centimeter scale shown.

Photo 8.
Algal stromatolite, about eight feet from bottom of lower section. Centimeter scale shown.

Photo 9.
Cross bedded laminations about ten feet from top in lower section. Six inch scale shown.

Photo 10.
Ripple marks on top of lower section. Six inch scale shown.

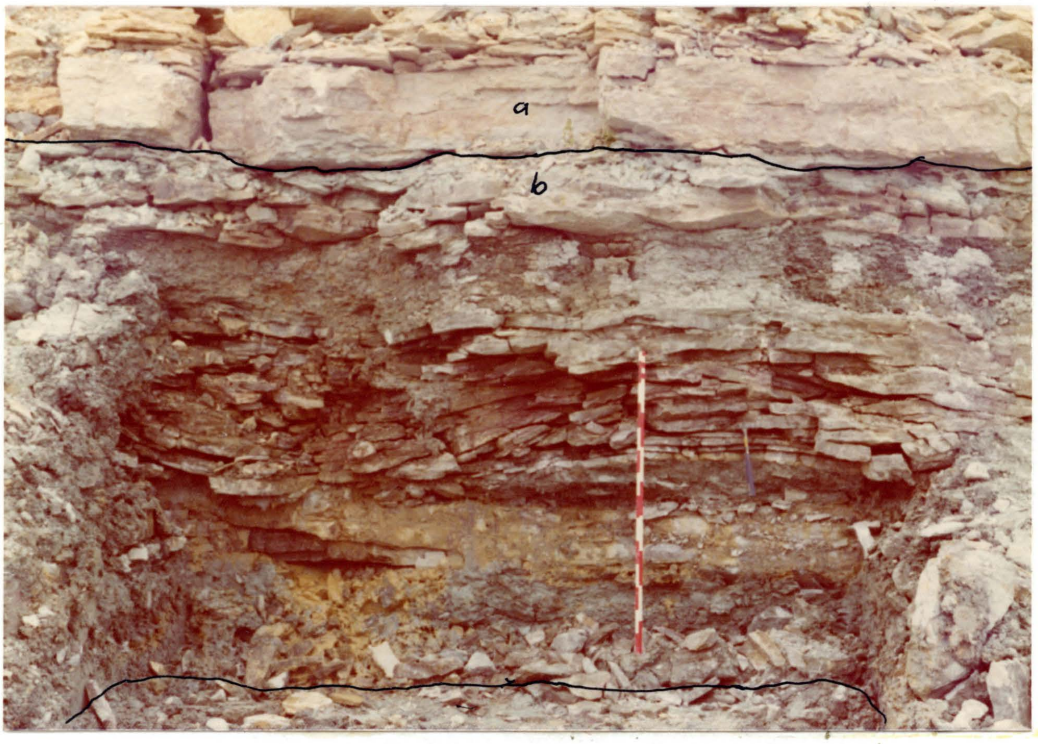


Photo 11.
View of location of upper section showing Dayton Formation (a) and Brassfield Formation (b). Scale 10 centimeters (left) and six inches (right).

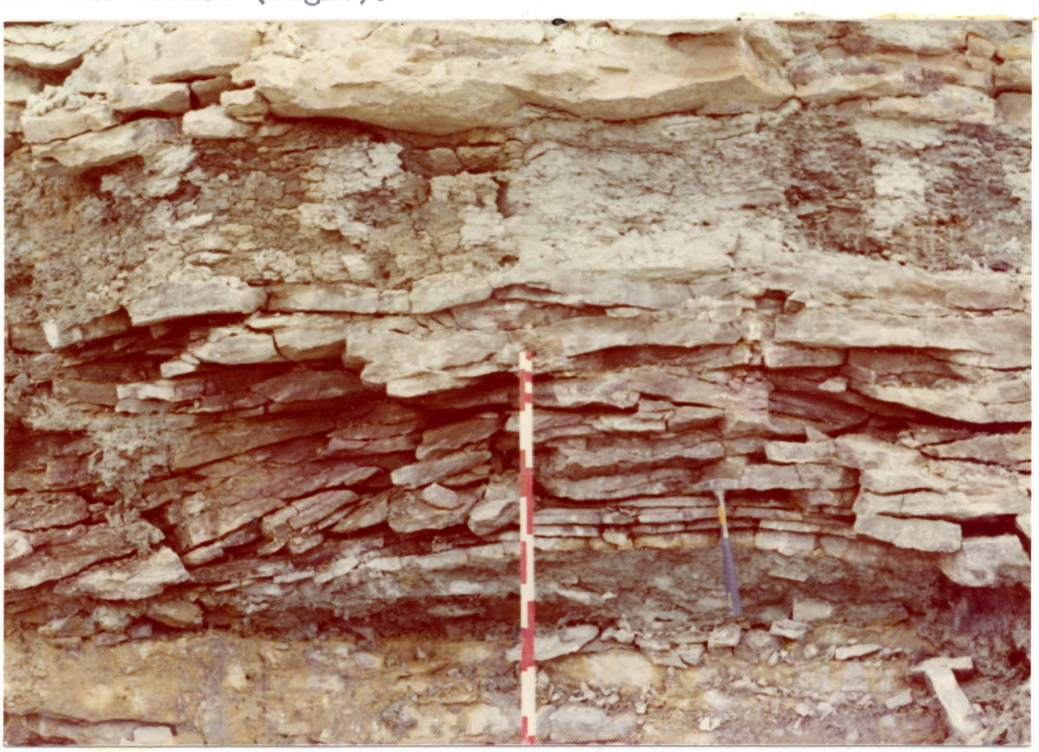


Photo 12.
Extreme undulations in bed in middle of section. Scale ten centimeters (left) and six inches (right).

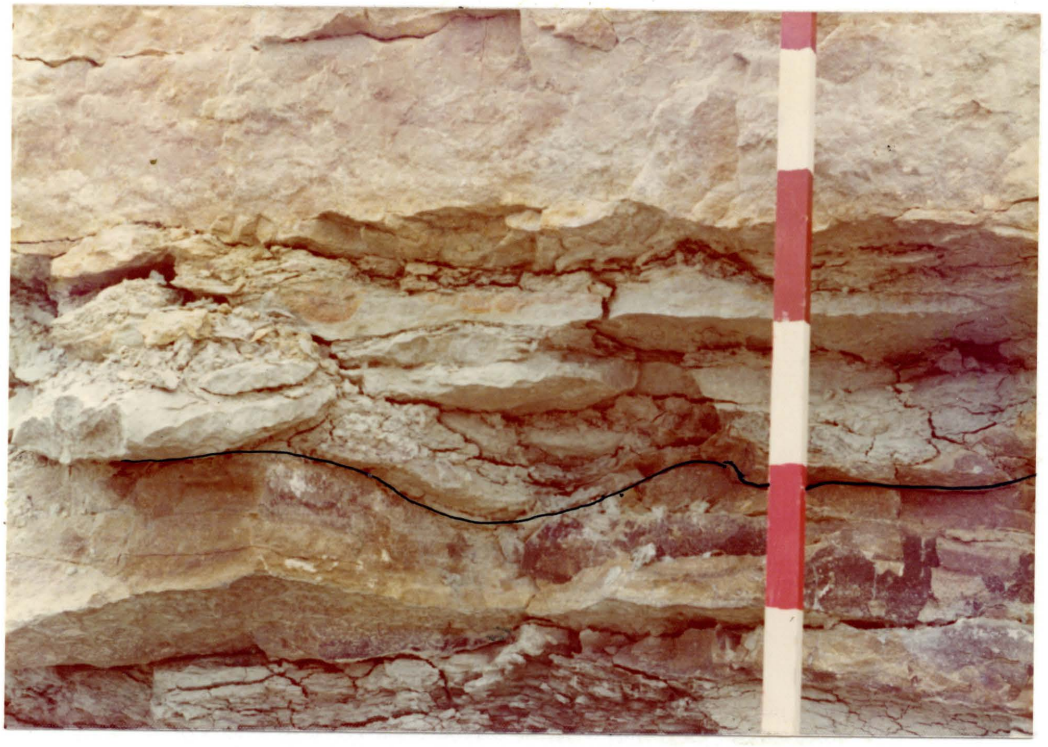


Photo 13.
Channel cut into limestone six inches below Dayton Formation. Scale ten centimeters.

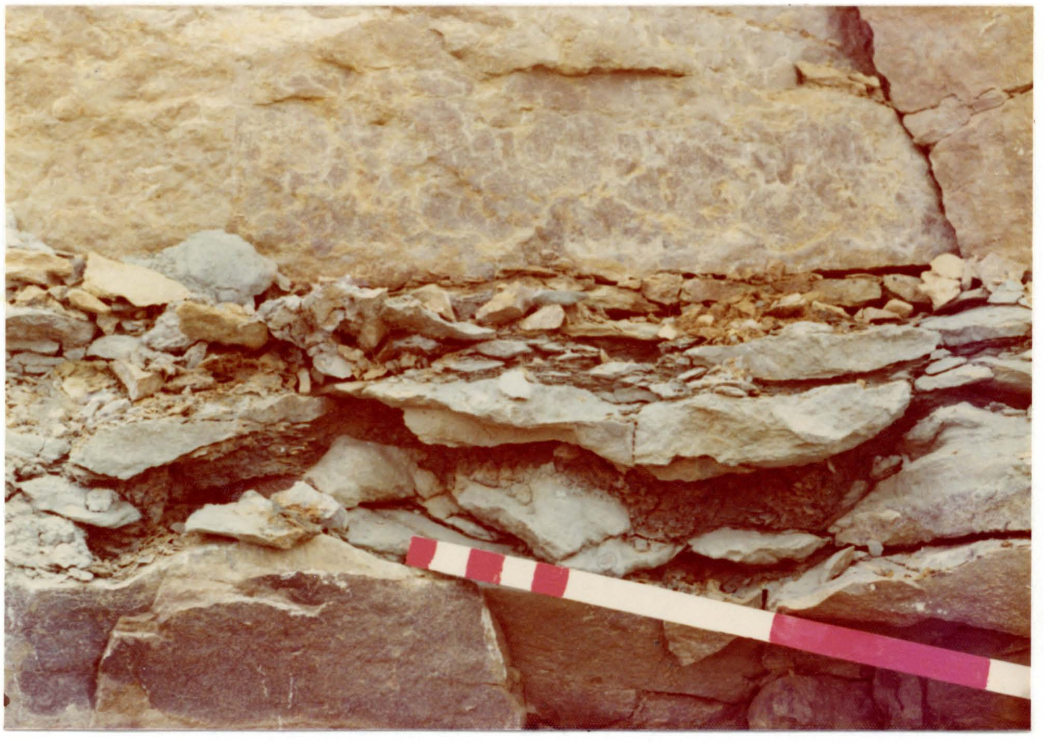


Photo 14.
Sandy lenses about six inches below Dayton Formation. Scale six inches.

Photo 15.
Ripples in limestone about six inches below Dayton Formation. Scalesix inches (upper) and ten centimeters (lower)

Photo 16.
Liquid clay about one foot above bottom of section. Scale six inches (left) and ten centimeters (right).

Photo 17.
Laminated sandstone layer in lower section, interbedded with carbonates below. Negative of peel, 1X.

Photo 18.
Slightly laminated limestone from upper part of lower section, about ten feet from top. Negative of peel, 2X.

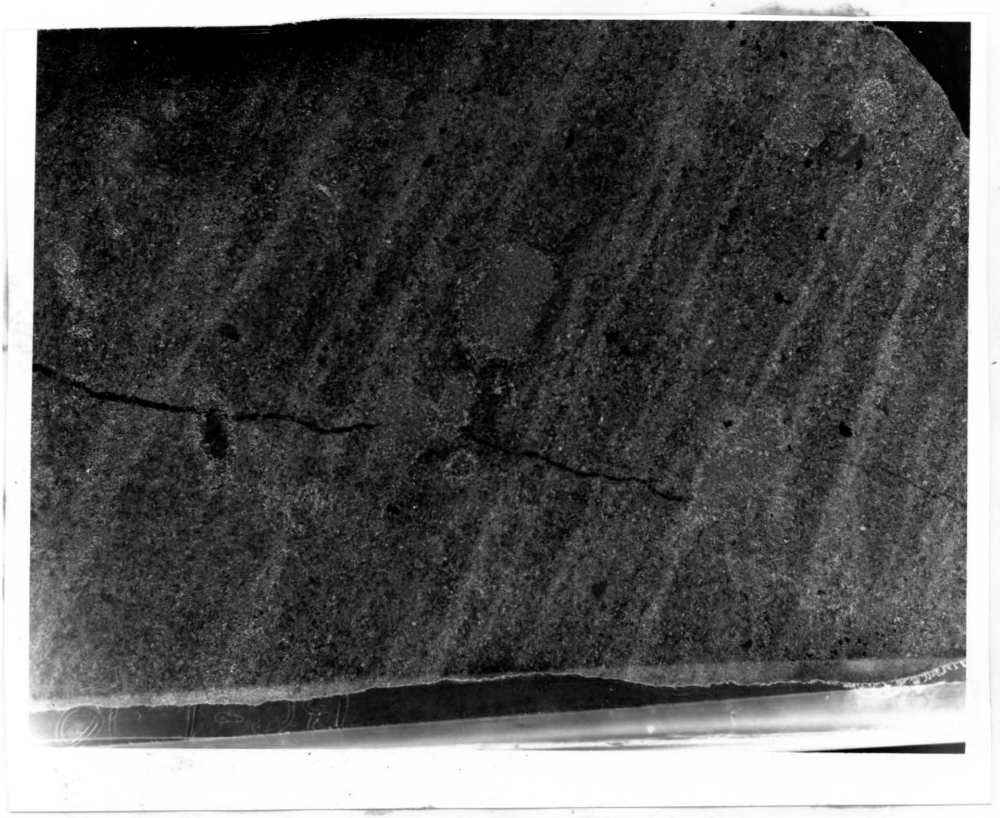


Photo 19.
Laminated limestone with worm burrows filled with silt, from about four feet below top of lower section. Negative of peel, 2X.

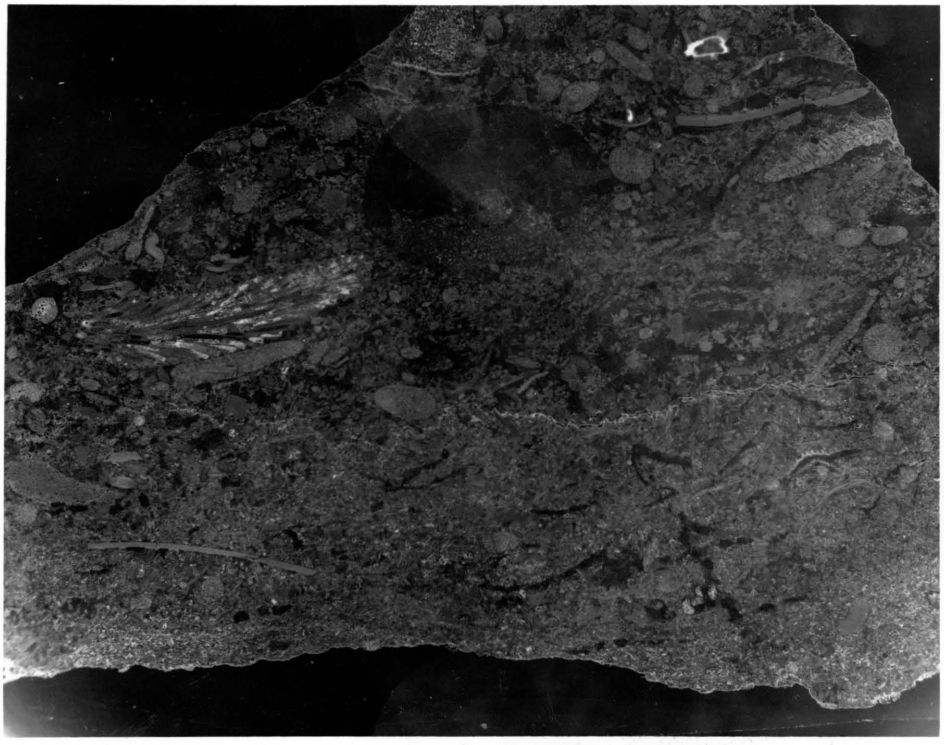


Photo 20.
Fossiliferous limestone from about two feet below top of lower section. Negative of peel, 2X.

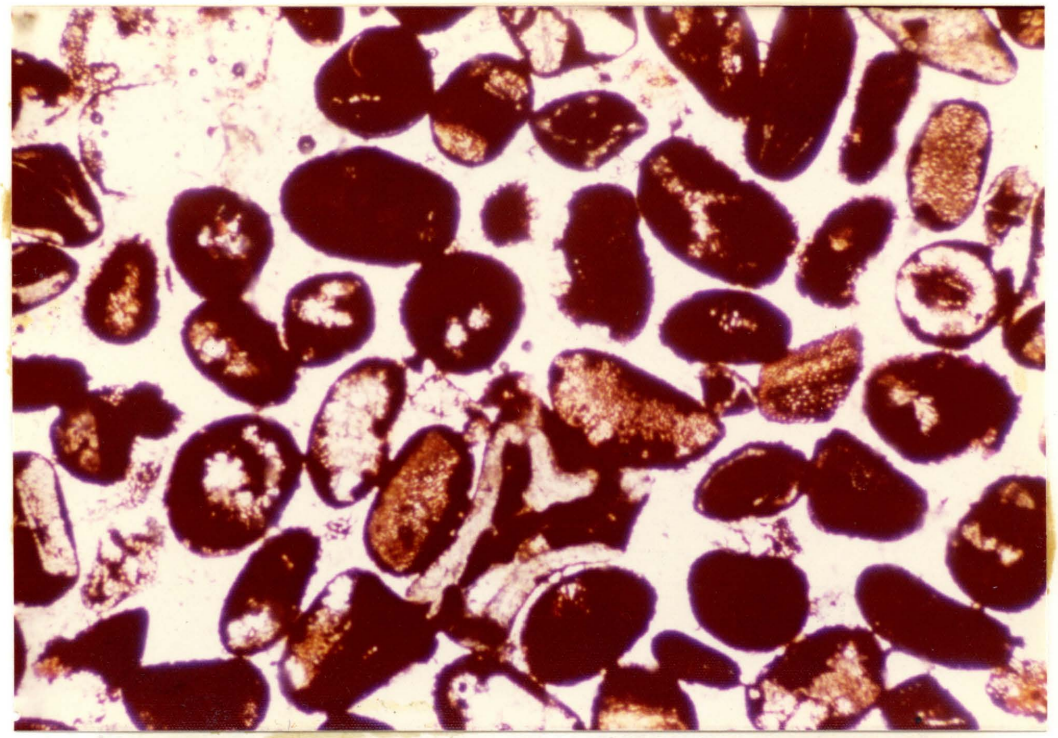


Photo 21.
Sand derived from echinoid and bryozoan debris with calcite mosaic cement. Photomicrograph, 25X.

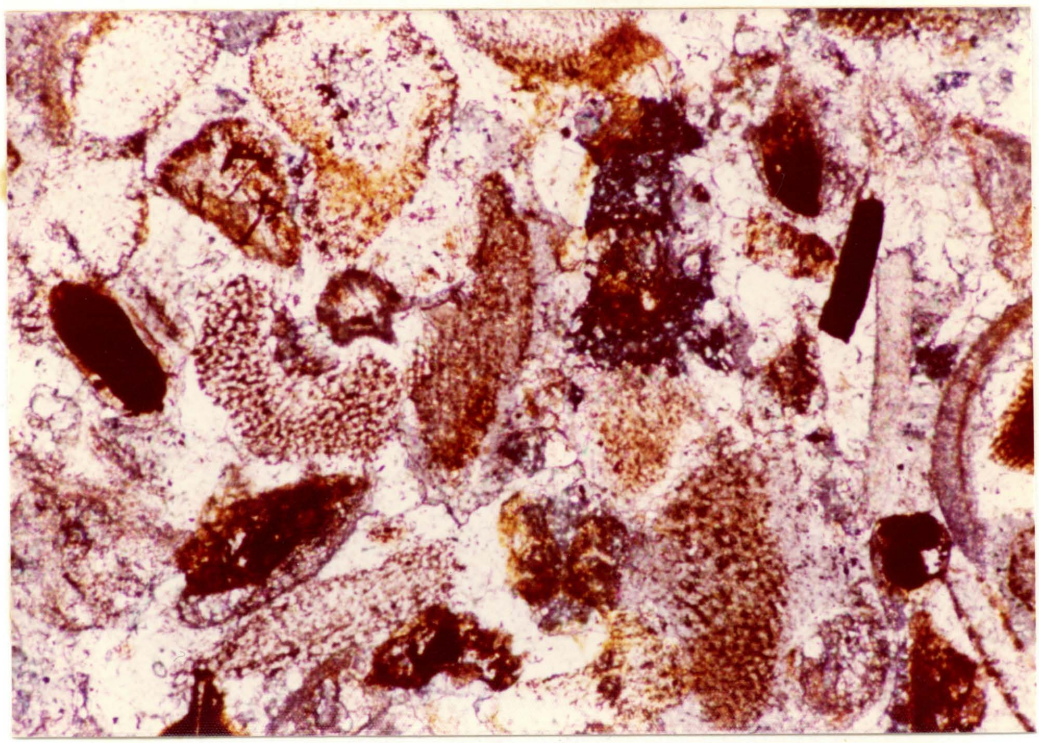


Photo 22.
Echiniod sand from last unit of limestone in upper section. Photomicrograph of thin section, 25X.

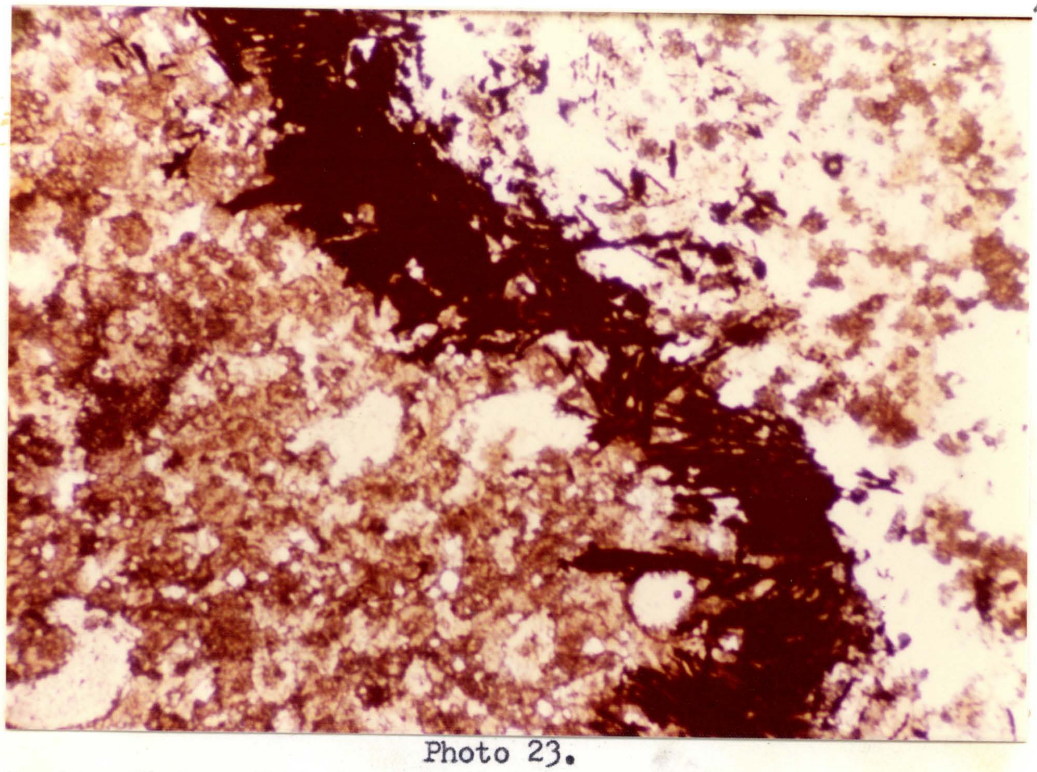


Photo 23.
Pyrite flakes from last limestone unit in upper section. Photomicrograph of thin section, 25X.

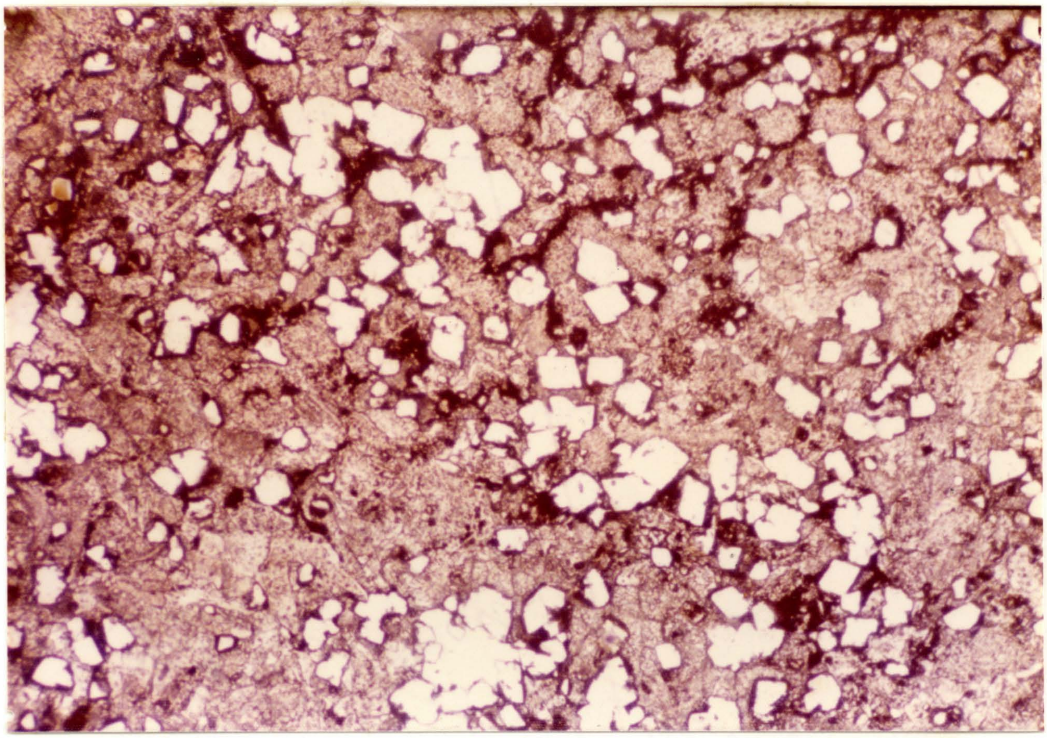


Photo 24.
High degree of dolomization from top unit of lower section. Photomicrgraph of thin section, 25X.

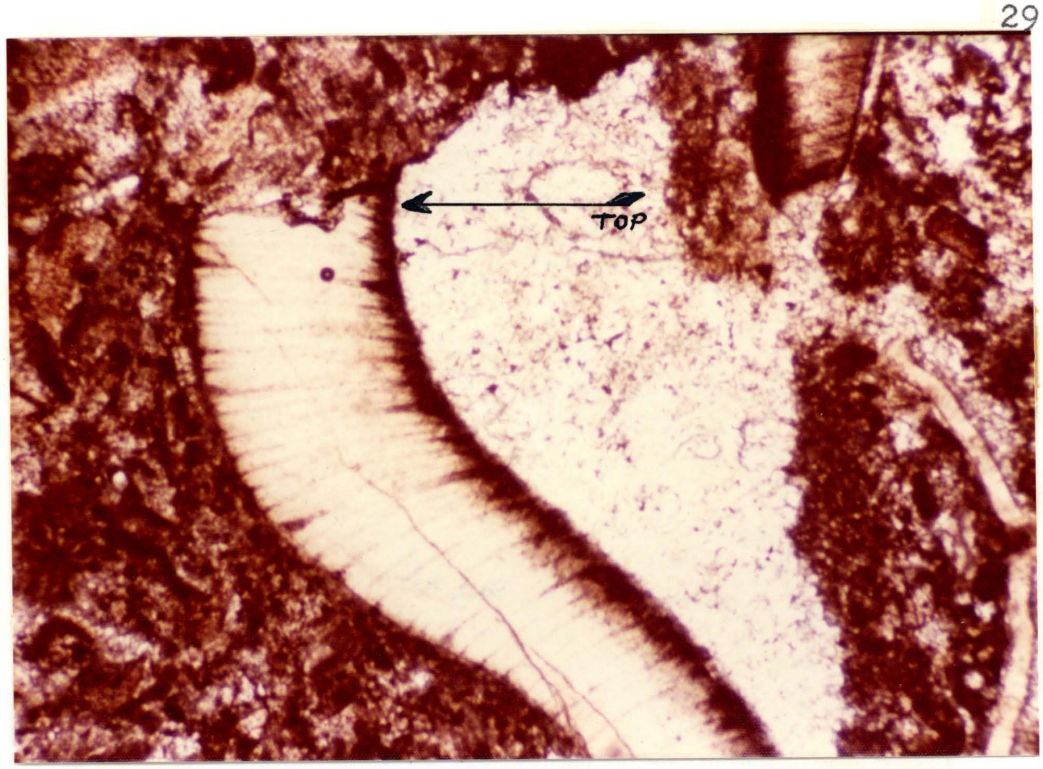


Photo 25.
Silt and calcite mosaic filling void left by trilobite. Photomicrograph of thin section, 25X, bottom of upper section.

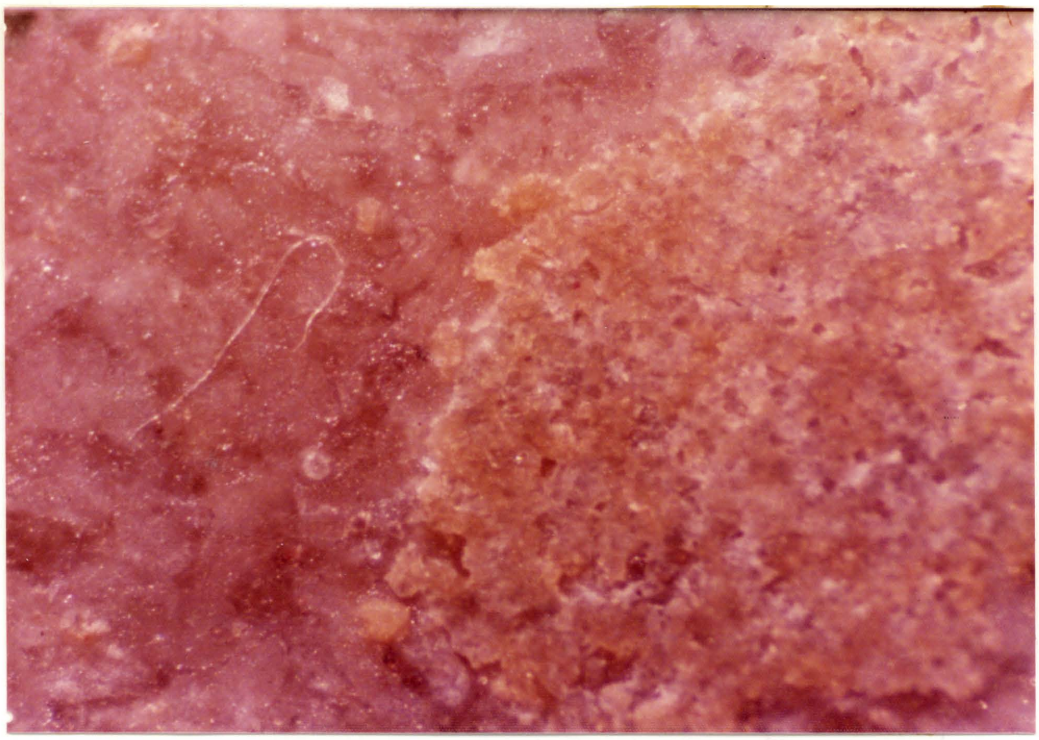


Photo 26.
Silt filled worm burrow from about four feet below top of lower section. Photomicrograph of rock slab under reflected light, 25X.

CONCLUSIONS

These studies of the Brassfield have shown that:

1. The Brassfield represents one transgression and regression of a sea of lower Silurian time, with a minor incomplete regression during the middle of the deposition.
2. The Brassfield was deposited in a relatively shallow basin, probably not more than fifty to one hundred feet. The region was extremely level, such that a minor raising or lowering of the sea level was sufficient to move the shore great distances.
3. The upper levels of the Brassfield at this site represent a beach and deltaic deposit. The beach deposit is composed of echinoid debris and bryozoans, probably derived from another area.
4. The basin may have been formed by settling of the area around the Cincinatti Arch, known to have been developing during Silurian times (Rogers, 1936).
5. The large rounded grains found in the upper section are not oolites as has been stated by previous investigators (Foerst, Orton, Rogers, Hopkins) but represent rounded echinoid fragments at this site.

BIBLIOGRAPHY

Berry,W.B.N., and Boucot, A.J., Correlation of the North American Silurian Rocks, Geol. Soc. Amer., Special Paper no. 102, 1969.

Black, Rhona M., The Elements of Palaeontology, Cambridge University Press, Cambridge, Mass., 1972.

Foerste, a.f., An Account of the Middle Silurian Rocks of Ohio and Indiana, Including the Niagara and Ohio Clinton, and the Bed at the Top of the Lower Silurian Strata, Formerly Considered the Medina, Jour. Cin. Soc. Nat. Hist., vol. 18, pp. 161-199, 1896.

Hopkins, Roy M., Jr., A Petrographic Study of the Brassfield Limestone in Southwestern Ohio, Unpublished Masters Thesis, The Ohio State University,1954.

Horowitz, A.S. and Potter, Introductory Petrography of Fossils, Springer Verlag, New York, 1971.

Matthews, Robley K., Dynamic Stratigraphy, Prentice-Hall, Inc, Englewood Cliffs, New Jersey, 1974.

Orton, Edward, The Geology of Highland County, Ohio Geol. Surv. Rep of Progress for 1870, pp. 255-310, 1871.

Rogers, James K., Geology of Highland County, Ohio Geol. Surv., Fourth Series, Bulletin 38, Col, 1936.

APPENDIX

Stratigraphic column of lower section of Highland Stone Division Quarry, three miles west of Hillsboro, Highland County, Ohio. Column taken fifty feet north of ramp leading from floor to bench on east wall of quarry.

unit	thickness	description
1	8 feet	Limestone, medium gray, medium grained, uneven bedding, weathers slightly yellow, undulating beds, a bed of possible algal mats about one and one half foot from the top
2	2-3 inches	Clayey shale, dark gray with a greenish tint, thin bedded, fractile, wet
3	40-45 inches	Limestone, medium gray, medium grain, clastic, lenses o f shale partings, lenses of abundant fossils, beds undulatory
4	1 inch	Shale, medium gray, very thin bedded, friable
5	20-24 inches	Limestone, medium gray, medium grained, some darker lamelli, many chert nodules, abundant pyrite, shale partings, undulatory uneven beds
6	½-1 inch	Shale, medium gray, very thin bedded, friable
7	6-7 inches	Limestone, medium gray, medium to coarse grain, slightly laminated. isolated bryozoan and brachiopod fossils
8	4 inches	Sandstone, light gray, with slight greenish tint, very fine grained, very thin even bedding, grades into limestone at bottom, grades into siltstone at top, thins to the north
9	2-3 inches	Shale, dark gray, very fine bedding, some clay, chunky
10	2-4 inches	Limestone, light gray, medium grained, silty, no fossils
11	6 inches	Muddy shale, medium gray, thin bedded, chunky
12	20-24 inches	Limestone, light gray, medium grained, uneven bedding, less silt to bottom, laminated, cross bedded, thin shale partings, isolated bryozoans
13	½ inch	Shale, medium gray, very thin bedded, fractile
14	1 inch	Limestone, light gray, fine grained, some silt, slightly laminated, no partings
15	½-3/4 inches	Shale, medium gray, very thin bedded, fractile

unit	thickness	description
16	10-12 inches	Limestone, light gray, fine grained, some silt with less near bottom, slightly laminated, a few partings
17	½ inch	Shale, medium gray, very thin bedded, fractile
18	2-4 inches	Limestone, light gray, medium grained, slightly laminated, uneven bedding, horn corals
19	3/4 inch	Shale, medium gray, very thin bedded, fractile
20	10-11 inches	Limestone, light gray, medium grained, uneven undulating beds, shale partings, worm burrows and possible algal mats, lenses of coarser bioclastic material
21	½ inch	Shale, medium gray, very thin bedded, fractile
22	2-6 inches	Limestone, medium light gray, medium grained, isolated thin shale lenses, some bryozoans
23	½ inch	Shale, medium gray, very thin bedded, fractile
24	17-19 inches	Limestone, medium light gray, medium grained, uneven thin beds, possible algal mats, isolated thin shale partings near bottom
25	9-12 inches	Limestone, light gray, medium grained with coarser fragments, dolomized lenses, lenses of abundant fossils, undulating uneven beds

Stratigraphic column of upper section of Highland Stone Division Quarry, three miles west of Hillsboro, Highland County, Ohio. Column taken one hundred twenty five feet north of ramp leading from floor of quarry to bench on east wall of quarry.

unit	thickness	description
1	7 inches	Limestone, light gray, small grains, even bedded, fossils sparse
2	10 inches	Silty clay, medium gray, greenish tint near top, friable, a few thin lenses of siltstone near bottom
3	2-3 inches	Clay mud, yellow brown, liquid, some interbedding with unit below
4	10-12 inches	Limestone, light gray, small grains, fairly even beds, fossils sparse
5	4-10 inches	Clay, medium gray with greenish tint, beds to $\frac{1}{4}$ inch, lenslike shape, may be local
6	28-30 inches	Limestone, medium gray to dark gray to red to brown, fine to coarse grains, clastic, beds very undulatory, cross bedded, abundant fossil fragments, some smaller channels to four inches deep cut into top, some ripples at top
7	15 inches	Siltstone, medium gray with green near top, yellow near bottom, red to south, thin bedded, friable, chunky
8	3-9 inches	Limestone, medium gray to yellow to reddish brown to black, medium grained, mudcracks, ripple marks, isolated brackiopods
9	1-5 inches	Shale, light gray with bluish tint, silty, thin sharply curved beds, cross beds, worm burrows, crinoids, brachiopods.
10	1-1$\frac{1}{2}$ inches	Dolomitic limestone, yellow gray, fine grained, black inclusions
11	$\frac{1}{2}$-1$\frac{1}{2}$ inches	Shale, greenish gray, thin bedded, friable, discontinuous due to unconformity at top
12	24 inches	Dolomitic limestone, yellow gray, fine grained, Dayton formation