A STUDY OF PENNSYLVANIAN SANDSTONES IN THE MAYFLOWER RESIDENCE HALL AREA IOWA CITY, IOWA

BY

ROBERT T. KAY

ABSTRACT

Pennsylvanian sandstones in the Mayflower Residence Hall area can be broken down into five units from bottom to top. Unit A consists of black and grey shale with fine grained sandstones interbedded, representing flood basin deposition. Unit B contains a buff, moderately sorted, fine- to- very- fine- grained subarkosic arenite, representing crevasse splay deposition. Unit C is a micaceous, bioturbated arkosic wacke with abundant iron sulfide nodules, representing deposition on a flood plain. Unit D is a wacke sandstone with siderite replacing calcite cement, that appears to have been deposited on a flood plain. Unit E is a well sorted, fine grained subarkosic arenite. Unit E has eroded part of unit D and shows features which indicate that it is a channel deposit. All units contain carbonized plant fragments. The stata dip a few degrees to the east, toward the center of the channel.

These sandstones are mineralogically and texturally mature, showing that they have been reworked at least once after erosion from an igneous/metamorphic complex to the north, the Canadian Sheild being the most likely source area.

The sequential diagenetic history of these sandstones is one of carbonization of plant fragments, cementation by Ca carbonate, formation of pyrite nodules, precipitation of calcium carbonate with dissolution of quartz, precipitation of quartz overgrowths

and silica cementation, ironstone formation followed by hematite cementation and alteration to limonite. The last events to occur were fracturing and fracture filling with iron carbonate.

All available evidence indicates that these sandstones are within the Cherokee Group.

INTRODUCTION

The study area was confined to the Pennsylvanian rocks in the vicinity of the Mayflower Residence Hall of Iowa City, Iowa. The goals of this study were to 1. Map the Pennsylvanian units present in the area and describe their lithologies. 2. Determine the mineralogy, diagenesis, and depositional environment of these lithologies. 3. Attempt to determine the stratagraphic relationships between these sandstones and the standard Pennsylvanian section in the Midcontinent. Previous investigations in this area on these rocks have been distinguished but few. Calvin (1897 p. 83) identified specimens of <u>Leipidodendron</u> in these strata. Calvin studied the lithologies of this area and concluded that the channel width at this site was as narrow as 300m. In the absence of detailed data from earlier workers, a complete investigation of the area was necessary. Outcrops were plotted on the map and lithologies were described. All measurements were made with a tape measure. Lithologic boundaries were mapped based on actual observation and position of the float until an understanding of the extent of the

Pennsylvanian in the area was reached (see fig. 1). Samples were collected, numbered, and their position in the strata was noted. These samples were made into thin sections, and mineral identification was accomplished using standard optical mineralogy techniques as outlined by Shelly (1980). Q:F:R ratios were determined by point counting 224 to 288 individual grains per sample. Names of sandstones are based on a modificaton on the classification scheme of Folk (1968), with the arenite/wacke boundary set at 20% matrix. Grain size and sorting determinations were made through grinding and sieving the samples then comparing their weight percent with their grain size which was measured in phi units.

GEOLGICAL SETTING

During the Pennsylvanian age the Mayflower Residence Hall area was part of a vast, uplifted erosion surface bounded by the Mississippi River Arch to the east, the Forest City Basin to the south, the Transcontinental Arch to the west, and the Canadian Shield to the north (see fig. 2).

DESCRIPTION OF LITHOLOGIES

Pennsylvanian sandstones in the Mayflower Residence Hall area of Iowa City represent deposition by a meandering river system that existed upon the eroded pre-Pennsylvanian surface atop the Devonian Cedar Valley Limestone. The sandstones are subdivided into five units from bottom to top. Unit A, the lowest visible unit, consists of a black to grey shale with well sorted, interlaminated to interbedded, fine grained sandstone (see fig. 3,4). Unit B lies above unit A and is composed of a buff colored, moderate to well sorted (see fig. 5), fine to very fine grained subarkosic arenite. Unit B also contains abundant interlaminations of carbonized plant fragments and black shale (see fig. 6). In some areas unit B displays cross laminations of sandstone and grey shale. Unit C is next in the sequence, it is a micaceous arkosic wacke (see fig. 7), with carbonized plant fragments and black shale interlaminations. In unit C, iron sulfide nodules mark areas where bioturbation has occurred (see fig. 8). Unit D overlies unit C and is an arkosic wacke (see fig. 9). Unit D is micaceous and contains abundant carbonized plant fragments along with black shale interlaminations. This unit is cemented by calcium carbonate in most areas, particularly the upper half, which has been partially altered to siderite, pyrite nodules are also present. Unit D also displays leisagang cementaion patterns (see fig. 10), carbonate fracture fillings, and repetitive fining upwards sequences. Unit E lies on an erosion surface that cuts into unit D (see fig. 11). At the contact between units D and E is an ironstone rich area. Unit E is comprised of micaceous grey and red, fine grained, well sorted, (see fig. 12) arkosic arenites and siltstones, the siltstones being present at the base of the unit. Features present in the unit include load casts, high angle channel fill structures, leisagang cementation patterns, cross bedding, possible ripple marks, clay-chip conglomerates, evaporite casts, and conglomerate casts.

All units except for units A and E show carbonate cementation in at least some areas of the unit. Load casts present in unit E indicate a southwest trend to the channel in this area, though since this is a meandering river system, nothing definite about direction of the flow can be stated from a study of such limited geographic extent. A highly schematic cross section of the Pennsylvanian lithologies is presented in fig. 13.

MINERALOGY AND TEXTURE

The analysed samples from the sandstone units contain very little variation in the percentages of quartz, feldspar, and lithic fragments (see figure 14). Rock fragments, predominately chert and metamorphic fragments, constitute about 2% of the rock in each sample. Feldspars comprise about 26% of each sample. Quartz accounts for about 72% of the grains in each sample analized. All samples present contain similar accessory minerals, with rutile, corundum, zircon, and muscovite present in at least trace amounts. Tourmalilne, epidote, orthopyroxene, garnet, and augite were observed in at least one sample. With the exception of units C and D, where muscovite is present in significant amounts, acessory minerals account for no more than 5% of the sandstone (see fig. 15). Carbonate cement is an important component of units B, C, and D where it often replaces quartz as seen in thin section (see fig. 16). Clay matrix accounts for a significant portion of the sandstones in units C and D. Unit A, B, and E sandstones consist of grain supported frameworks exhibiting no in situ grain deformation that may be attributable to post depositional compaction. Larger grains of quartz often show quartz overgrowths and quartz and feldspar grains are often held together by silica cements in the pore spaces, the source of the silica being the dissolved quartz grains which were replaced by carbonate in high pH conditions and migrated in solution to lower pH areas where precipitation occurred around existing grains (Walker 1960). Quartz overgrowths generally join several grains together (see fig. 17) but do not form a significant portion of the binding material in the rocks. Original quartz grain boundaries are sometimes discerned by dust rims which surround them (see fig. 18). Quartz overgrowths are often surrounded by hematite and limonite as seen in thin section. Iron sulfide nodules vary in size from spheres approximately 3mm in diameter, to nodules measuring 7cm in width, 3cm in height, and 10cm in length. Iron sulfide particles surround sand grains and show the original bedding features. Iron sulfide nodules are surrounded, on occasion, by carbonate. Thin section and modal analysis reveals that the grains in the sandstones are generally subangular to rounded, moderate to well sorted, and have mostly long contacts with each other. The sandstones are generally friable, except in the ironstone area or where cemeted by carbonate. In the carbonate cemented areas, calcium carbonate has been partially replaced by iron carbonate.

INTERPRETATION OF MINEROLOGY

The detrital component of the sandstones indicates that the source for these sandstones was a igneous terrain which may have undergone some metamorphism. The possibility of polycyclic sedimentation cannot, however, be overlooked. Source area interpretation is based on the mineralogy of the sandstones. (Shelley 1980) Zircon is a common accessory mineral in igneous rocks. Tourmaline is most commonly characteristic of granite pegmatites and the rocks immediately surrounding them. Muscovite and corundum are found in both igneous and metamorphic rocks. Garnet is a widespread mineral in metamorphic rocks. The presence of this stable heavy mineral assemblage in these sediments suggests that the source area was an igneous/ metamorphic complex. The Canadian Sheild to the north is the most likely source area for the sandstones. The presence of this stable heavy mineral assemblage does leave open, however, the possibility that this resistant, mature sandstone is at least in part the product of sedimentary recycling.

GEOCHEMISTRY AND DIAGENISIS

To understand the diagenesis of these sediments it is necessary to recognize the importance of the bacterial decay in the area which may have increased the ammonia and carbonate concentrations in the pore water solution. This bacterial activity reduces the plant matter to carbon and sets up a strongly reducing, high pH environment in which iron sulfide nodules are formed (Fairbridge 1967), occasionally surounding plant fragments. Plant matter was a probable source of the iron and sulfur as well as a source of the carbonate for the cement in unit D. After precipitation of iron sulfide, carbonate partially replaced quartz grains in high pH zones in units B and C. Carbonate replacement continued in the units in some instances surrounding iron sulfide nodules. The dissolved quartz migrated to areas of lower pH and precipitated around existing grains forming quartz overgrowths. As conditions became slightly more oxidizing, calcium carbonate was replaced by iron carbonate. As the channel water became introduced into the area, Eh conditions became oxidizing. These channel waters invaded unit D and, along with the groundwater, oxidized the siderite to produce hematite ironstone, which occurs at the contact between units D and E. Groundwater then invaded the rest of the unit, oxidizing more siderite to hematite. Hematite then became hydrated to limonite. Some hematite also formed due to precipitation from groundwater in the other units, often surrounding quartz overgrowths. Late in the diagenetic history of this area, fracturing of unit D occurred, separating leisagang patterns of the hematite and limonite. Some of the fractures were filled by carbonate derived from unit D.

The paragenetic sequences for the Pennsylvanian sandstones in the study area is as follows;

1. Carbonization of plant fragments.
2. Formation of iron sulfide nodules.
3. Carbonate cementation and replacement of quartz in unit D.
4. Carbonate replacing quartz in units B and C.
5. Formation of quartz overgrowths.
6. Calcite replacement by siderite.
7. Dissolution of fragments in the southernmost outcrop.
8. Ironstone formation at the unit D/unit E contact.
9. Hematite cementation through much of the area.
10. Alteration of hematite to limonite.
11. Fracturing of unit D.
12. Fracture filling with carbonate.

Geochemically, the area has undergone a change from very reducing to oxidizing Eh conditions, and from high to lower pH conditions.

DEPOSITIONAL ENVIRONMENT

The Pennsylvanian sandstones in the Mayflower Residence Hall area of Iowa City were deposited by a meandering channel system (see fig. 19). Unit A, with its black and grey shales, was deposited in a flood basin that was subjected to repeated influxes of coarser-grained sands from overbank flooding. Unit B, with its low angle ripple marks, horizontal laminations of plant material, and paucity of fine-grained materials, indicates the repeated overbank flooding of a high energy crevasse splay. Unit C displays a smaller degree of sorting and significant quantites of silt sized particles. The abundant, horizontally laminated plant matter, the bioturbation features, and the presence of small, easily transported grains, indicates unit C was deposited on a flood plain. Unit D was also deposited on the channel flood plain. Evidence for flood plain deposition includes the repetitive fining upward cycles, the poor sorting, the abundance of silt and silt sized grains, and the presence of horizontally laminated plant matter in unit D. Unit E displays an erosional surface into unit D, load casts, conglomerate casts, ripple marks, rip up clasts, and cross bedding. All of these features indicate that unit E was deposited by the river channel and that the exposure south of the Mayflower may be a point bar facies of the channel.

CONCLUSIONS

Taking into account paleogeographical considerations (Fitzgerald 1977), source region interpretation, the southwesternly direction marker present in the channel facies (even though its value is limited), and the Q:F:R ratios of the sandstones, which make the rocks arkoses and sub arkoses, instead of quartz arenites or lithic arenites like those described by Fitzgerald (1977), indications are that the rocks in the Mayflower Residence Hall area belong to the Cherokee group and represent deposition by a river channel whose trend in this area was probably close to that of the Iowa River, and whose ultimate destination was the Forest City Basin (Lemish 1981).

Figure 1

Outcrop map of the study area. The Pennsylvanian is orange the Devonian is in green, and alluvium is yellow. Outcrops are numbered and colored more heavily. The approximate Devonian/Pennsylvanian contact is outlined in blue pen.

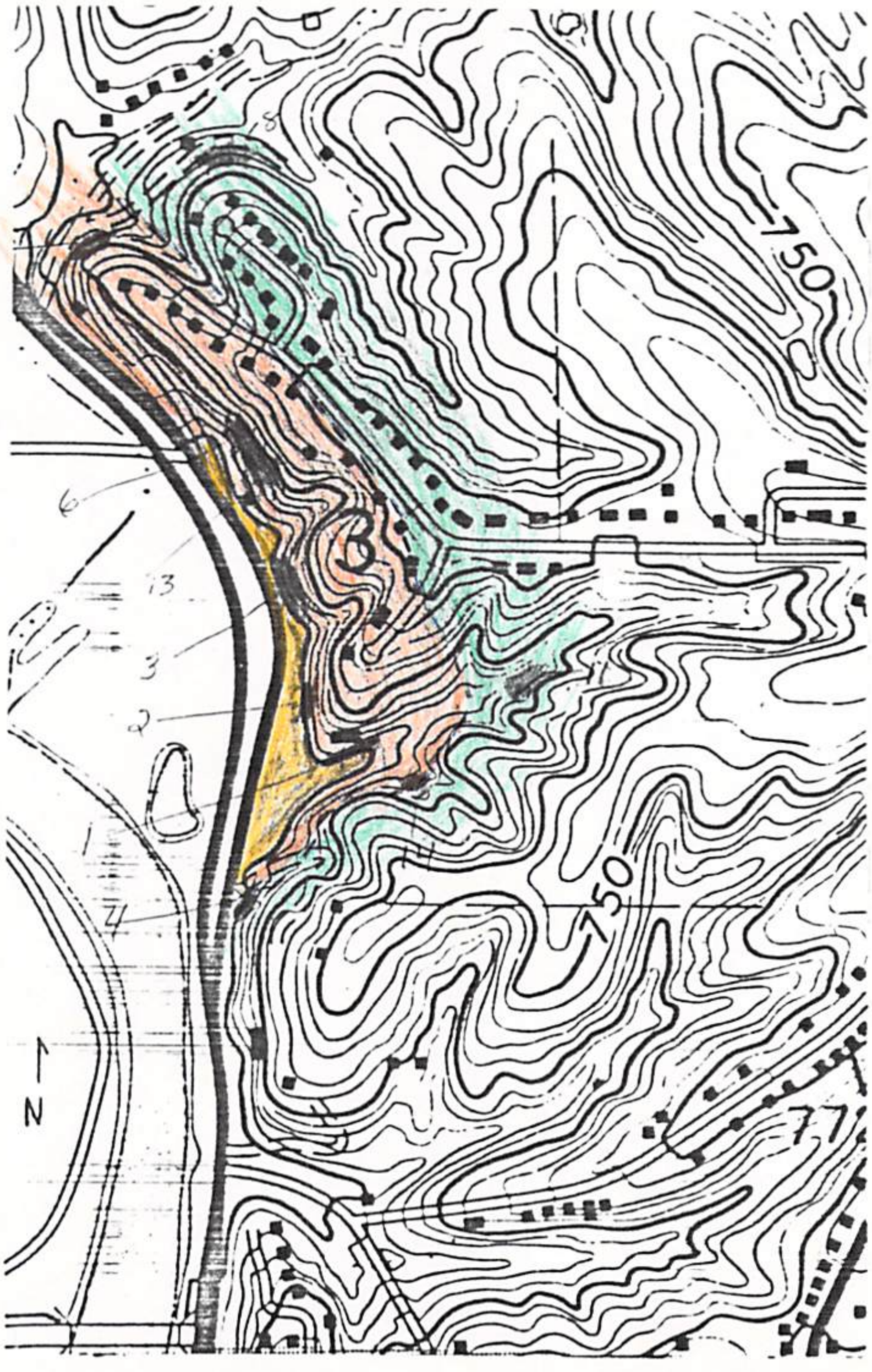
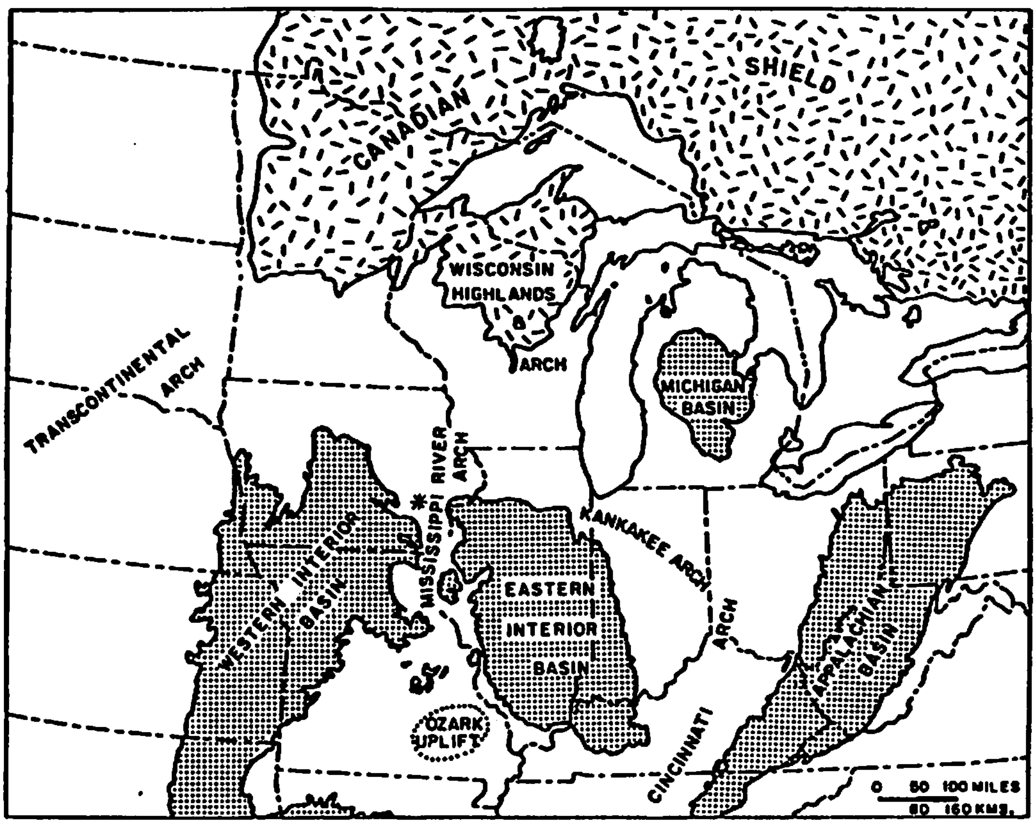


Figure 2

Paleogeographic recontruction of the mid-continent region during the Pennsylvanian. * denotes Iowa City.



UNIT A

```
   90|               *
W    |               *
E  80|               *
I    |               *
G  70|               *
H    |               *
T  60|               *
     |               *
%  50|               *
     |               *
   40|               *
     |               *
   30|               *
     |               *
   20|               *
     |               *
   10|               *     *
     |        *      *     *     *
    0|   *    *      *     *     *
     ----|----|------|-----|-----|--
     0   1    2      3     4     5
```

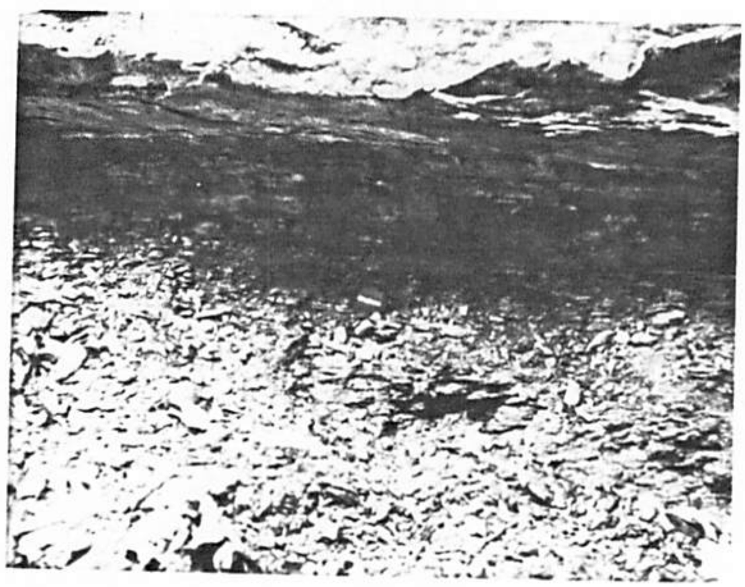
GRAIN SIZE (PHI)

figure 3

Grain size vs Weight % distribution for three samples of Unit A sandstones.

FIGURE 4

Picture of Unit A in outcrop. Note the interbeds of shale and sandstone.



UNIT B

```
    50|                  *
W     |                  *
E   40|                  *
I     |                  *
G   30|                  *
H     |                  *     *
T   20|                  *     *
      |                  *     *     *
%   10|                  *     *     *
      |            *     *     *     *
     0|      *     *     *     *     *
  ------|-----|-----|-----|-----|--
        1     2     3     4     5
```

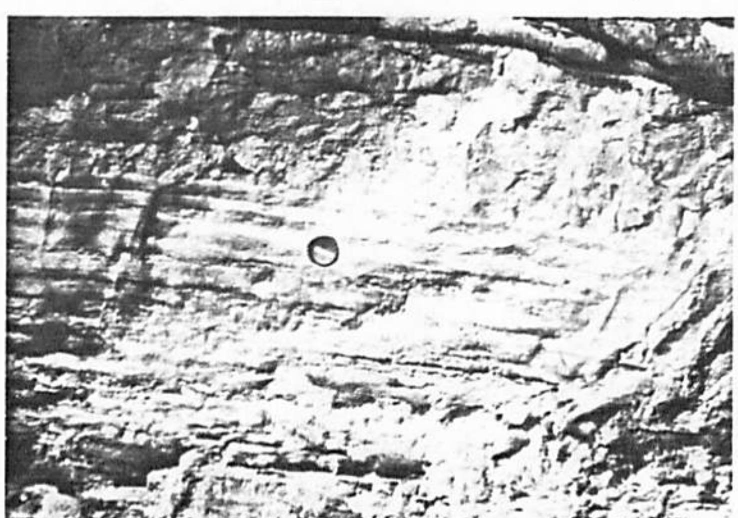
GRAIN SIZE (PHI)

figure 5

Grain size vs Weight % distribution of four samples from Unit B.

Figure 6

Picture of Unit B in outcrop



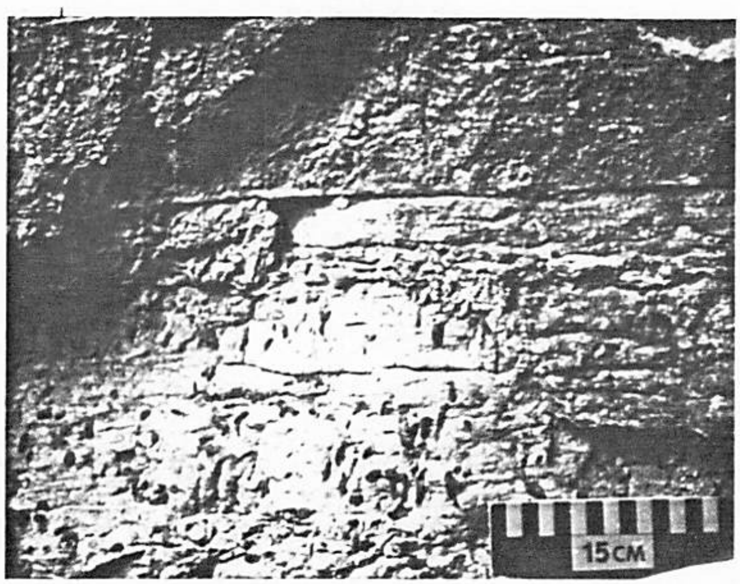
```
            UNIT C

   40|               *
W    |               *
E  30|               *         *
I    |               *         *
G  20|               *         *
H    |         *     *         *
T  10|         *     *    *    *
     |    *    *     *    *    *
%   0|    *    *     *    *    *
     -----|----|-----|----|----|--
          1    2     3    4    5

              GRAIN SIZE (PHI)
```

Figure 7

Grain size vs Weight % for three samples from Unit C.

Figure 8

Picture of Unit C in outcrop. The protruding nodules are iron sulfide and denote where bioturbation has occurred.



UNIT D

```
   70|
W    |                         *
E  60|                         *
I    |                         *
G  50|                         *
H    |                         *
T  40|                         *
     |                         *
%  30|                         *
     |                         *
   20|                         *
     |          *              *
   10|          *    *    *    *
     |          *    *    *    *
    0|     *    *    *    *    *
     ------|----|----|----|----|--
           1    2    3    4    5
```

GRAIN SIZE (PHI)

Figure 9

Grain size vs Weight % for seven samples from Unit D.

Figure 10

Leisagang cementation pattern as seen in Unit D.

Pyrite nodule at lower left

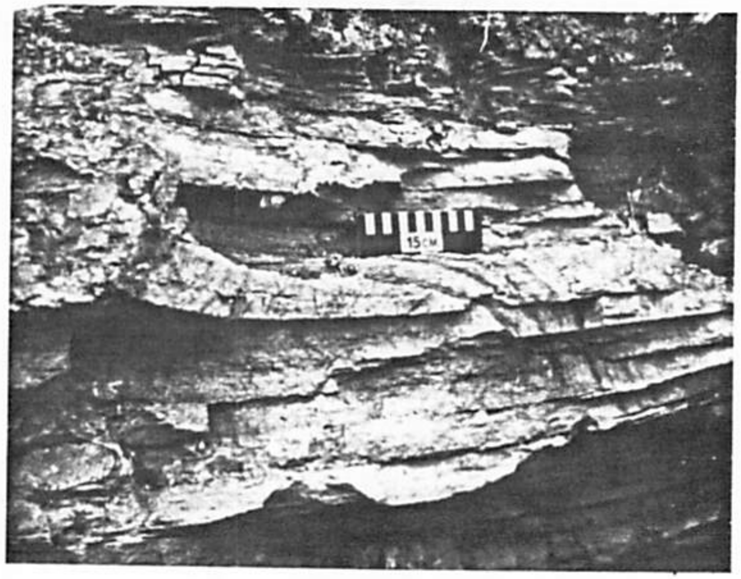


Figure 11

Unit D overlain by Unit E. Erosional surface present at the contact can be discerned. Several layers of Pleistocene sediments cover Unit E

UNIT E

```
   50|               *
W    |               *
E  40|               *
I    |               *
G  30|          *    *
H    |          *    *
T  20|          *    *
     |          *    *
%  10|          *    *    *    *
     |     *    *    *    *    *
    0------|----|----|----|----|--
           1    2    3    4    5
```

GRAIN SIZE (PHI)

Figure 12

Grain size vs Weight % of six samples from Unit E.

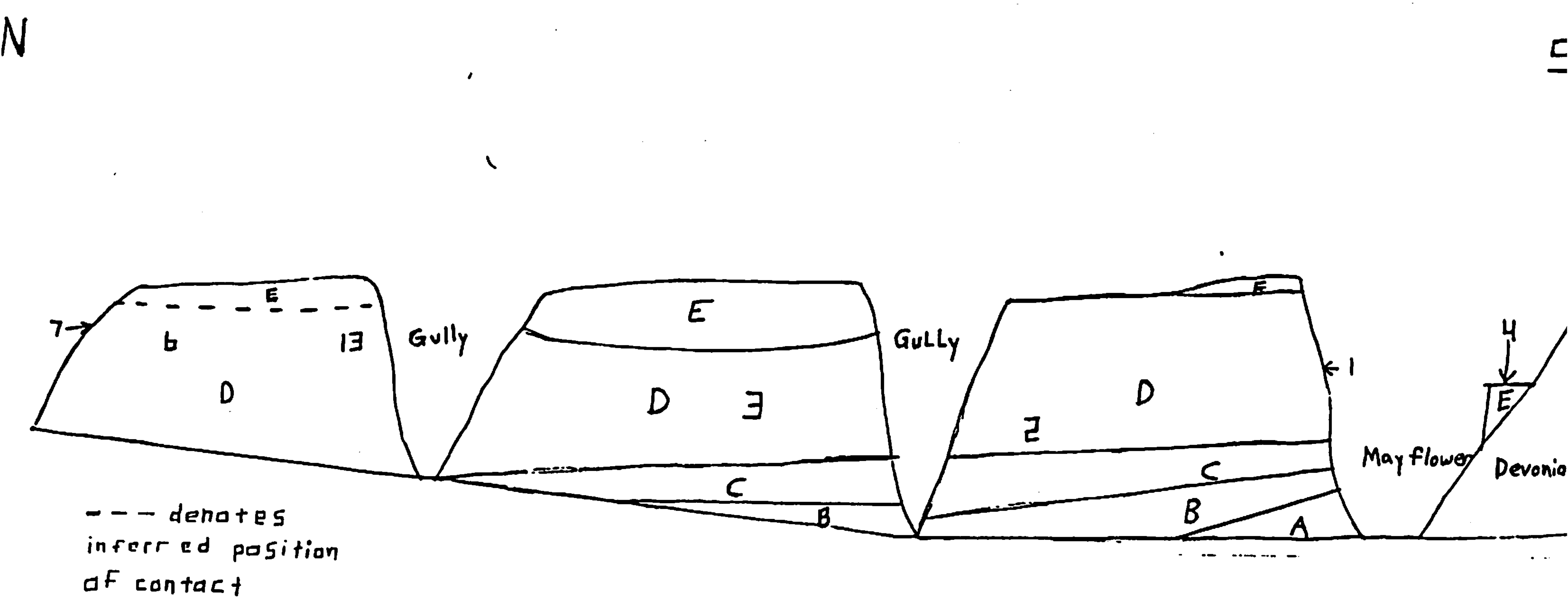
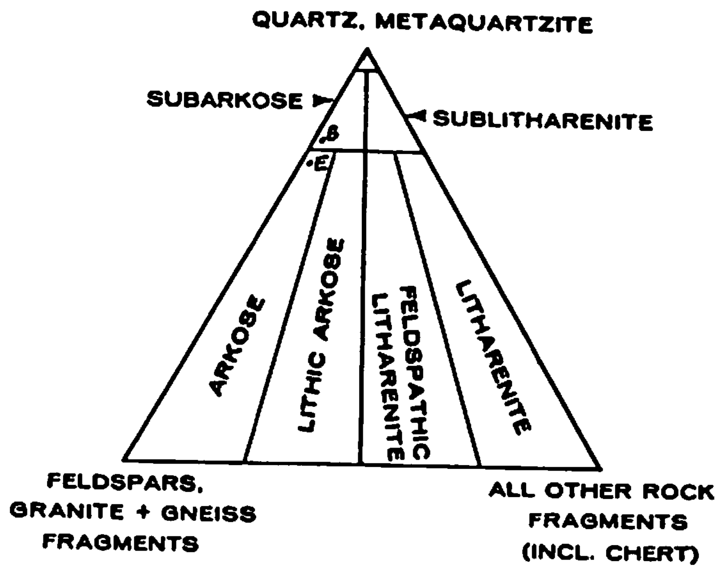


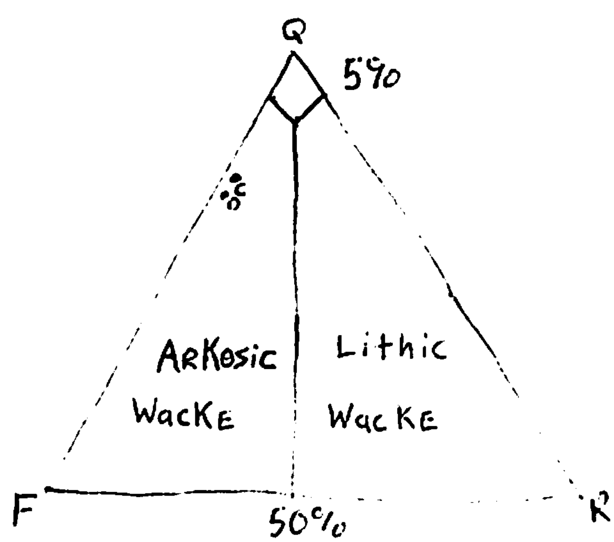
Figure 13

Schematic cross section, facing east, of the Mayflower area. Each unit is denoted by its letter. Position and number of outcrop is noted on the map. (Cross section is not to scale)

Figure 14

Q:F:R diagram displaying the mineralogy of one sample per unit, the unit the sample belongs to is denoted by its letter.





	UNIT B sample 4		UNIT C sample 11		UNIT E sample 52	
	#	%	#	%	#	%
Quartz	155	69.2	185	64.2	190	66.0
Feldspar	51	22.8	69	24.0	76	26.4
Lithic frag.	3	1.3	3	1.0	4	1.4
Mica	1	0.4	18	6.3	6	2.1
Corundum	1	0.4	1	0.3	3	1.0
Zircon	4	1.8	3	1.0	1	0.3
Rutile	2	0.9	1	0.3	2	0.7
Magnetite/ Ilmenite	2	0.9	4	1.4	4	1.4
Tourmaline			2	0.7	2	0.7
Augite	2	0.9	1	0.3		
Epidote			1	0.3		
Garnet	1	0.4	1	0.3		
	224	99.0	288	99.8	288	100.0

Figure 15

Modal analysis of one sample from Units B, C, and E.

Figure 16

Carbonate replacing quartz in a sample from Unit C. The opaque mineral is pyrite, which is surrounded by carbonate in this sample. View is in cross polarized light.

Width of field of view is 1mm.

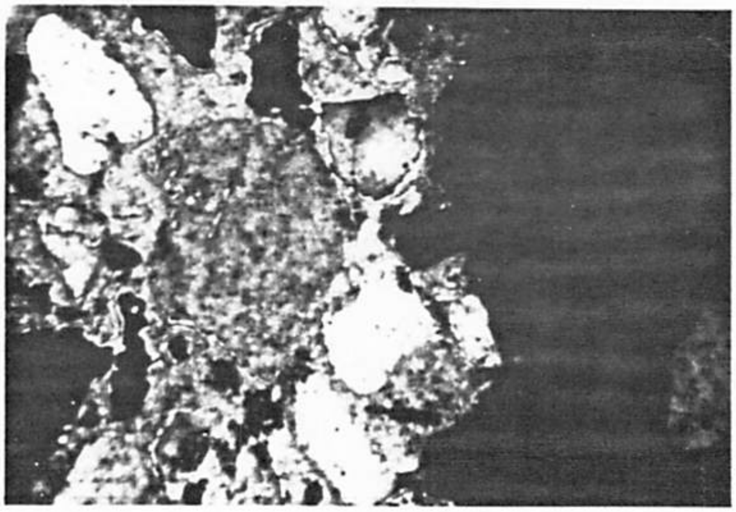


Figure 17

Detrital grains cemented together by diagenetic quartz overgrowth as seen in cross polarized light.

Width of field of view is 1mm.

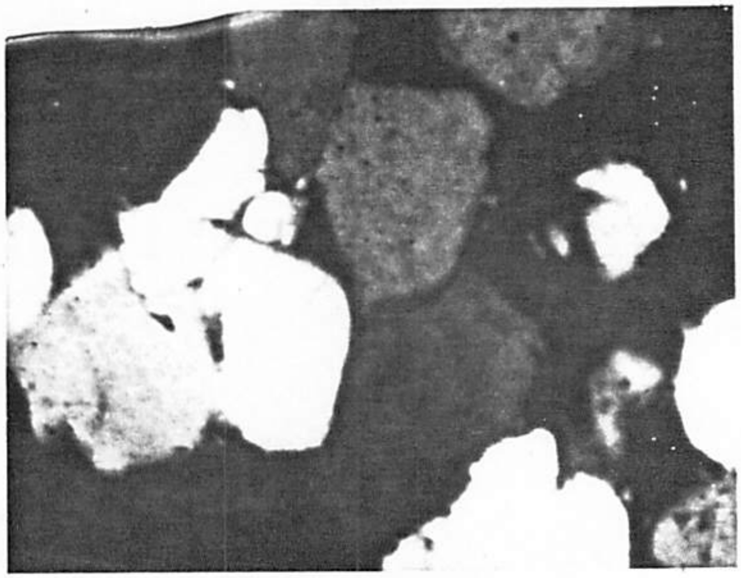


Figure 18

Same view as fig. 17 but in plane polarized light. Note the dust rims which define the original grain boundary.

Width of field of view is 1mm.

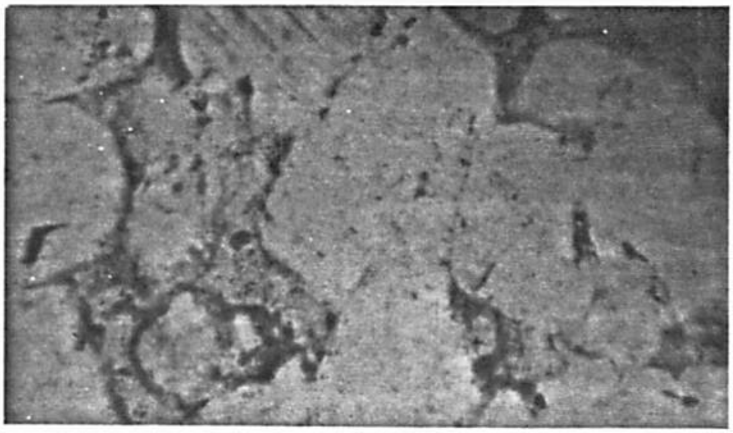
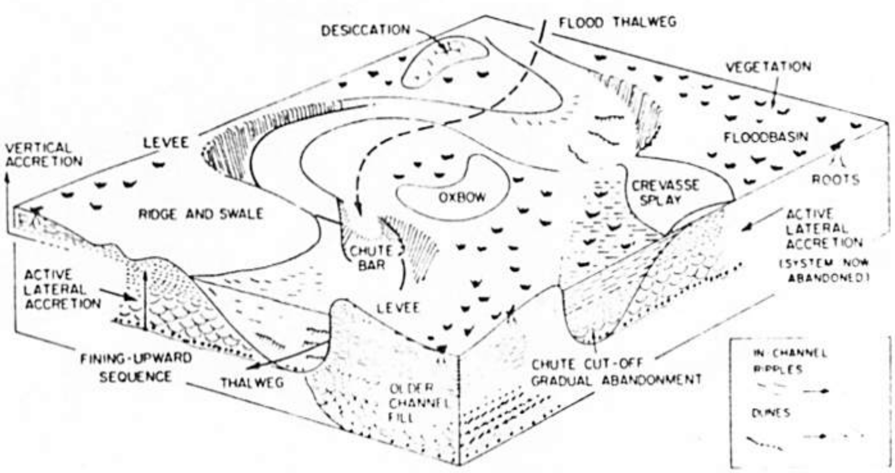


Figure 19

Model adapted from Walker 1979 showing a meandering river system and its related facies.



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B. Kay

The Pennsylvanian units in this area can be divided into five basic units at this stage. Unit A is lowest in the stratigraphic section, it is at least 1.22m thick and is comprised of interbedded grey shale, black shale, and shaly sandstone. Unit A is visible in outcrop 1. Unit B is the second unit from the bottom, measures .91m in thickness, and is comprised of fine grained sandstone and black shale interlaminated though it is predominately sandstone. Unit B is visible in outcrops 1 and 3. Unit C lies above unit B, measures .61m in thickness, and is comprised of a fine grained sandstone with black shale interlaminated but it also contains iron oxide at all angles to bedding which has occupied space that may have been created through bioturbation. Unit C is visible in outcrops 1 and 3. Unit D lies above unit C, it is the thickest unit present measuring 8.5m. This unit is comprised of interlaminated black shale and fine-grained sandstone, ~~and~~ contains nodules of iron sulfide cementing material, ~~and~~ displays cementation patterns at high angles to the bedding plane, and has many fractures. Unit D is seen in outcrops 1, 2, 3,6,7, and 13. Unit E is a course grained, poorly cemented sandstone with numerous pores that are the molds of earlier material, probably wood or rock fragments. This unit is .76m thick, displays cross bedding, evaporite molds, and possible ripple marks and load casts. Outcrops 4 and 2, and possibly outcrops 3,5 and 7 contain rocks of unit E. Thin section analysis will allow a determination of mineralogy and textural maturity, from this data an interpretation of the depositional environment, diagenetic history, and source area will be made. Attempts will also be made, based on thin section analysis, to determine what formation these rocks belong to. Preliminary data indicate that the depositional environment for unit A was a flood basin, the depositional environment for unit B was a channel, unit C was deposited on a flood plain, and units D and E were deposited in a river channel.

North-South Stratigraphic cross section (Not to scale)
(#) - denotes outcrop and number