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STRATIGRAPHY AND DEPOSITIONAL HISTORY OF THE PENNSYLVANIAN SEQUENCE EXPOSED AT THE CAGLE'S MILL SPILLWAY PUTNAM COUNTY, INDIANA

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ABSTRACT

The Early Pennsylvanian Mansfield Formation outcrop at the Cagle's Mill spillway cut is an extensive and complex display of interbedded sandstone and shale bodies. Two episodes of deltaic progradation into a shallow water body are recorded in these rocks. An orbiculoid brachiopod in the lowermost unit indicates progradation of the first delta into a shallow marine environment.

Delta front and delta plain depositional environments, much modified by fluvial processes, dominate the Cagle's Mill rocks. Several types of fluvial sedimentation include cut and fill by lateral migration, channel fill by vertical accretion and deposition by crevasse splay.

INTRODUCTION

The Cagle's Mill spillway, section 13, T. 12N, R. 5W, southern Putnam County, Indiana is described in reconaissance fashion by Langenheim *et al.* (1966). The purpose of this project is to define in detail the major stratigraphic units, their sedimentary structures and petrology as well as to propose an environmental interpretation of the complex.

MATERIALS AND METHODS

Approximately 6 days were spent in the field during October and November, 1982. Major stratigraphic units were defined and their relationships documented. Also, specimens were collected for thin sectioning and petrographic study. Several of the shale and mudrock units, however, were not thin sectioned because of their fissile or unconsolidated nature.

RESULTS AND DISCUSSION

General Geologic Setting

The Cagle's Mill spillway cut exposes the Early Pennsylvanian Mansfield Formation and overlying Kansan and Illinoisan till (Langenheim *et al.* 1966). In this area the Mansfield Formation unconformably overlies the Middle Mississippian Ste. Genevieve Limestone, which is exposed at the outlet tunnel of the Cagle's Mill dam.

General Geology of the Spillway

Major rock types exposed are fine-grained quartz arenite and fine-grained lithic quartz arenite, both with interbedded shale layers. Carbonaceous quartz arenite is abundant. Shale and coal are minor constituents in the cut but a thick shale sequence crops out along the road north of the spillway.

Virtually all units exposed in the cut are truncated by one or more erosion surface (figs. 1, 2) precluding definitive measurement. Therefore, approximate thicknesses only are reported where appropriate.

Individual rock units of distinctive environmental significance are designated by number (figs. 1, 2).

Stratigraphy and Depositional Environments

Units 1a, 1b, 1c and 1d

The basal unit exposed in the spillway is approximately 27 feet of shale and silty shale. This sequence is divided into 4 units; 1a, 1b, 1c and 1d based on macroscopic lithologic character. These units are too friable for thin sectioning but a thin section of a siderite concretion occurring in unit 1a is available.

Unit 1a, the lowermost rock exposed in the area, is very poorly exposed and its character is inferred mainly from talus samples. The unit consists of approximately ten feet of dark gray, carbonaceous, silty, quartzose shale. Rounded siderite concretions are not uncommon. Petrographic analysis of a concretion indicates moderate bioturbation. Angular quartz silt comprises as much as 35% of the concretion. One orbiculoid brachiopod (fig. 3) was found in this unit. Unit 1a is conformably overlain by unit 1b.

Unit 1b consists of approximately 10 feet of gray to light gray, poorly bedded to massive, silty mudstone. Absence of fissility and poor bedding are attributed to bioturbation. This unit is conformably overlain by unit 1c.

Unit 1c consists of approximately 6 feet of very dark gray to black, organic, silty shale with sandy layers and lenses and several thin interbeds of gray mudstone resembling unit 1b. Bioturbation is rarely apparent. Lenticular and rounded siderite concretions stained with iron oxides are also present. *Cordaites* leaves and *Calamites* branches are abundant, especially near the top of this unit. Unit 1c is unconformably overlain by unit 2a which fills a channel cut into unit 1c. The lithologic character of unit 1c apparently undergoes a substantial change eastward where it abruptly changes into unit 1d. However, the nature of this relationship is not certain because the contact is obscured. Thus it is also possible that the contact may be somewhat gradational.

Unit 1d is best exposed immediately east of the lowermost eastern channel fill of unit 3 exposed on the north wall of the cut (fig. 2). It consists of moderately to poorly bedded, light gray mudstone and shale interbedded wavy laminae of sand, wedges of sandstone and some thin but apparently continuous beds of sandstone. All of the sandstone is fine- to very fine-grained. Plant fossils and carbonaceous rocks are abundant throughout.

Mudstone, sandstone stringers and abundant plant fossils indicate that this unit may be a variation of unit 1c. The poorly bedded gray mudstone of unit 1d differs substantially from the fissile, carbonaceous shale of 1c and the change occurs over an exceptionally short distance indicating an unconformable contact. Unit 1d is unconformably overlain by units 4a, 3 and possibly by unit 2a, the 2a-1d contact is unexposed.

Depositional Environment of Units 1a, 1b, 1c and 1d

The predominance of clay and silt particles and general fissility of these units suggest deposition in a very low velocity environment. The sandstone stringers indicate occasional increased competence. These characters, as well as the lack of animal fossils, presence of plant fossils and presence of sideritic concretions fits Wanless *et al.'s* (1970, p. 220-221) description of Pennsylvanian delta front muds very well. Bioturbation of delta front muds is well documented by Coleman (1976, p. 29-30). Lack of extreme bioturbation in most of these shales is attributed to low oxygen to anoxic conditions caused by the oxidation of the abundant plant material. This made the area unsuitable for burrowing organisms. Prominant bioturbation in unit 1b suggests that the poor oxygen conditions were replaced temporarily by more "normal" conditions. The change in oxygen concentration could be caused by a change in water chemistry, intermittent failure of a barrier to free circulation or a decrease in the amount of organic matter. The thin bioturbated and/or light gray layers within the dark gray shale of unit 1c indicate an abrupt change for a short period of time. Decrease in organic influx seems the most logical cause of this change.

The thickness of unit 1b implies a longer period of deposition without abundant organic material. This layer is approximately 10 feet thick and could conceivably be deposited in 15 to 20 years (Coleman, 1970, p. 48-49) assuming a compaction-dewatering ratio of 2:1. A decrease in organic matter for that period of time appears to be a more feasible explanation than a longer, more dramatic change such as the temporary opening of a restricted bay to open circulation.

Units 2a and 2b

Unit 2a unconformably overlies unit 1c and possibly unit 1d. It consists of 2 feet of massive, dark to very dark gray, well cemented, fine-grained sandstone with iron sulfate deposits on weathered surfaces. This fine-grained quartz arenite consists of 85% well sorted, subangular quartz, approximately 5% schist and phyllite grains and 5-8% clay minerals (fig. 4). Accessories, including metaquartzite, zircon, chert, microcline and tourmaline comprise 1-2% of the rock. Two episodes of cementation are evident; the first deposited syntaxial quartz overgrowths on the quartz grains and the second filled pores with iron pyrite. Unit 2a fines upward and grades into unit 2b.

Unit 2b is laminated and burrowed, quartzitic and lithic, carbonaceous shale. This unit is 6 inches thick where exposed but it is unconformably overlain by unit

3 and the true thickness is unknown. It consists of 40% fine-grained, angular quartz sand and quartz silt, 25% detrital clay minerals, 25% organic matter with secondary pyrite and 5-7% silty shale intraclasts (fig. 5). Much of the quartz sand is concentrated in burrow fillings. Accessories present include schist and phyllite, potassium feldspar, microcline, tourmaline, siltstone, muscovite and metaquartzite.

There are 3 mineralogically distinct types of internal laminae. These laminae average .5-1mm thick and each type is responsible for about one-third the total rock volume. The first type is dominantly carbonaceous matter with shale intraclasts; fine-grained quartz sand and clay minerals being much less abundant. The second type of laminae is mostly fine-grained quartz sand in a clay matrix with very little carbonaceous matter. The third type contains quartz sand, clay minerals and carbonaceous matter in about equal proportions. These laminae are irregular and discontinuous. Unit 2b is unconformably overlain by unit 3.

Environment of Deposition of units 2a and 2b

Units 2a and 2b are considered flood deposits on the delta front. The erosional base and massive sandstone at the base were produced by a short term rapid change in depositional conditions caused by an increase in flow velocity. The numerous shale intraclasts in unit 2b indicate active erosion of a mud substrate which is also indicative of increased flow velocities. As the flood waned, velocity decreased and the finer-grained, laminated material of unit 2b was deposited.

Layers 2a and 2b very closely resemble the A and B layers of a Bouma sequence (Blatt *et al.*, 1980, p. 145; Bouma, 1962, p. 48-54) which also is formed by a relatively large, short-lived sediment influx with decreasing flow regimes. Bed 2a appears equivalent to Bouma's A unit (1962) consisting of a graded, thick bed of the coarsest available sediment, here fine-grained sand. Bed 2b is similar to the B layer consisting of hydrodynamically lighter materials deposited in the planar phase of the upper flow regime as laminae. The C, D and E layers should be present if flow velocities decreased to relatively still water. Units 2a and 2b however, are truncated by an unconformity and these beds may have been removed by erosion.

Unit 3

Unit 3 unconformably overlies units 1c, 1d, 2a and 2b and consists primarily of cross bedded, lenticularly and planarly bedded fine- and very-fine grained, lithic quartz arenite with quartz and hematite cement. Silty shale and mudstone partings are not uncommon in this unit. Unit 3 is composed of repeated sequences representing repeated depositional events. Most sequences, however, are incomplete because of cut and fill processes.

The mineralogy of the lithic quartz arenites is virtually the same throughout the unit although proportions of the various constituents change somewhat from bed to bed. Grains of subangular, fine to very fine-grained quartz sand make up 60-80% of the rock. In some rocks the quartz grains are oriented with their long axis parallel to bedding, giving the rock a microbedded to micro-imbricated texture. Metamorphic rock fragments of schist and phyllite, generally larger than associated quartz grains are second in abundance. They constitute 10-15% of the rock in most cases but range from 2-20%. In some layers the metamorphic rock fragments are very abundant and compacted thus forming a pseudomatrix in which the quartz grains may float. Carbonaceous matter in these rocks is concentrated on bedding planes and ranges from 0-4%. Accessories in unit 3 include zircon, microcline, plagioclase, tourmaline, chert, potassium feldspar, metaquartzite and muscovite. Muscovite composes as much as 1% in a few of the samples.

Rocks in unit 3 exhibit 2 episodes of cementation. The first produced syntaxial quartz overgrowth on the quartz grains. This overgrowth appears a result of pressure solution processes as indicated by the widespread concavo-convex quartz grain contacts. Quartz cement is less well developed in rocks containing abundant metamorphic rock fragments. The second cementation filled virtually all pores with hematite cement. Much, if not all, of this cement may be derived from the alteration of schist and phyllite grains to hematite and sericite. This also may explain some of the difference in metamorphic rock content from bed to bed.

Although the mineralogy of the lithic quartz arenite is relatively uniform throughout the unit, grain size is bimodal and directly proportional to bed thickness. The thick-bedded sandstones are usually over 8 inches in thickness and contain grains 3 to 4 times as large as those of the more thinly bedded sandstone. There apparently is no gradation between the coarser-grained and finer-grained sandstone and the two probably represent a tractional and suspended sediment load (figs. 6, 7).

The sequential ordering of sedimentation in this unit is best viewed 15 to 20 feet west of the lowest resistant sandstone within the unit. This is approximately in the middle of the north side of the cut (fig. 8).

Each sequence rests on an erosional base. The lowermost subunit is cross bedded sandstone, that is as much as 5 feet thick, and may contain intraclasts. Dislodged pieces of this unit also have current ripples and trackways on bedding planes. This lower subunit grades into a thinly to lenticularly bedded sandstone subunit that ranges from a few inches to a foot in thickness. It is at this level that the dramatic decrease in grain size occurs. This second subunit grades into a thin, discontinuously planar bedded sandstone subunit with micro-cross laminae. Beds within this subunit do not persist horizontally for great distances. The planar bedded sandstone in turn grades into a light gray, silty shale subunit which generally is a few inches thick. Only the basal beds are present in most of unit 3 and they cut into one another giving the rock a lenticularly bedded appearance. The upper third of unit 3 is distinctly thin bedded, exhibits planar bedding and contains some shale partings. Unit 3 is unconformably overlain by units 4a, 4b and 4c.

Depostional Environment of Unit 3

Unit 3 is interpreted as a series of superposed point bar sequences deposited by a meandering stream, probably a deltaic distributary. This interpretation is based upon the prevalence of the immature, angular arenite with large percentages of metomorphic rock fragments (Potter, 1967, p. 344) and the repeated sedimentary sequences within this unit. These properties also occur in the meandering fluvial sand bodies described by Klein (1980, p. 26-27), Blatt *et al.* (1980, p. 636-639) and Reineck and Singh (1980, p. 267-274). Inference of a meandering nature of the stream is supported by paleocurrent data (fig. 9) indicating that the current direction differed as much as 90 degrees from a generally south southwestern direction. The most apparent digression from the descriptions of these authors is the lack of a lag deposit at the base of each depositional sequence. I attribute this to the deposition in a deltaic distributary as the coarser material would have been deposited far upstream. Several large intraclasts observed in this unit may be the counterpart of a lag deposit in this environment (fig. 10).

Units 4a, 4b, 4c, 4e and 4f

Unit 4a is the lowest of 5 units filling the major channel exposed in the cut. It consists of approximately 2 to 2.5 feet of fine-grained, angular quartz arenite with carbonaceous matter and metamorphic rock fragments. The upper part of this unit contains some interbedded silty gray shale. This sandstone is much "cleaner" than the sandstone in unit 3 with fine-grained quartz sand comprising 95% of the grains present. Three percent of the rock is grains of schist and phyllite and about 1% of the rock is carbonaceous material. Accessories present are zircon, tourmaline, muscovite, plagioclase, potassium feldspar and chert. The rock is pressure welded and cemented by incomplete quartz overgrowths. Sand sized grains of diagenetic iron pyrite are abundant throughout.

Unit 4a is limited to the channel floor and is poorly exposed. It is overlain by unit 4b in abruptly gradational contact.

Unit 4b consists of 4-8 inches of laminated silty gray shale. Unit 4b has an abruptly gradational contact with unit 4c.

Unit 4c consists of 6-8 inches of silty, carbonaceous black shale with coaly lenses. Unit 4c is the lowest channel filling unit to extend across the entire width of the channel. This unit has a rapidly gradational contact with unit 4d.

Unit 4d consists of as much as 2 feet of poor quality coal. The coal is mostly fusain and durain, vitrain being a minor constituent. The coal covers the entire channel floor being thickest at the bottom of the channel and thinning noticeably on the flanks. It is possible that the peat which formed this coal may have filled this channel in which case a constant channel depth/coal thickness ratio could be expected across the channel if peat compaction was uniform across the channel. Angular measurements taken to obtain these values give ratios of .062-.125, the average being .09. Channel depth/coal thickness ratios from measurements taken from photographs of the cut yield ratios of .06 to .11. The largest values are at the bottom of the channel and there is a systematic and uniform decrease toward the western flank. This suggests that approximately one-third more peat accumulated in the central part of the channel than on the outer edge. This effect could have been caused by compaction of the peat in the deeper part of the channel during peat accumulation allowing a greater volume of peat to fill the central part of the channel. Continuing subsidence within the channel with the greatest compaction in the midportion is also evidenced by downward bowing of the bedding in unit 4f (figs. 1, 2). Unit 4d is conformably overlain by unit 4e and unconformably by unit 5a.

Unit 4e consists of approximately 4 inches of black, fissile, silty, quartzose, carbonaceous shale. The weathered surface is bright orange and rosettes of gypsum crystals 1/4 inch in diameter occur on bedding planes. This unit is thickest at the center of the channel but thins somewhat on the flanks. This unit contained the only other invertebrate fossil noted in the entire complex, a small pelecypod poorly preserved as a carbonaceous film on a bedding plane.

The mineralogy of this rock (fig. 11) consists of 35% fine-grained sand and silt sized quartz grains all with their long axis parallel to bedding. Most of the quartz floats in a matrix of carbonaceous materials and clay which make up the remaining 65% of the rock. Some of the quartz, however, is concentrated in thin, lenticular laminae.

Unit 4e is conformably overlain by unit 4f and truncated laterally by unit 5a.

Unit 4f, the major channel filling unit in the cut, is a thin bedded (.15-.50 inch), silty, carbonaceous, gray, fine-grained quartz arenite. Beds are continuous and bow downward from the flanks of the channel into the center (fig. 2). Flaser bedding and microcross laminae occur in some of the beds.

Unit 4f consists of 80% subangular fine sand sized to silt sized quartz which is moderately well sorted (fig. 12). Carbonaceous material comprises 10-15% of the rock and detrital clay minerals account for 5-10%. Some of the specimens contain notable percentages of shale and metamorphic rock fragments. Accessories present include tourmaline, zircon, plagioclase, microcline, chert and muscovite. The rock has been bioturbated and rare shell fragments were noted in one thin section.

The rock has undergone 2 episodes of cementation. The first yielded a poorly-developed syntaxial quartz overgrowth cement. The second introduced a rare, void filling, hematite cement. Diagenetic pyrite is abundant in some specimens.

Unit 4f is unconformably overlain by units 5a and 7.

Environment of Deposition of Units 4a-4f

Units 4a and 4b are interpreted as the final depositional sequence in an abruptly abandoned stream course, as suggested by their thinness and fining upward character. The near proximity of deltaic deposits (Pryor and Sable, 1974), lack of coarse load and abundant organic matter suggest that this channel may have been a distributary eroding older deltaic sediments.

Upon channel abandonment and loss of competence the coarse load, represented by unit 4a was deposited in mid channel as this would be where the highest velocities and coarsest load would be located. The deposition of finer grained suspended materials, now comprising unit 4b, followed as current velocities decreased to zero.

Unit 4c represents the transition to suspension deposition in a stagnant environment. Here detrital material becomes less and less available in contrast to increasing organic accumulation leading eventually to peat accumulation. The very fine-grain, areal extent across the channel, fissility and organic rich composition indicate deposition from suspension under quiet, reducing conditions within the channel. As the stream was no longer active at this time the material was brought in during periods of high water on the deltaic plain. These deposits characteristically are composed of silty clay with much organic debris (Coleman, 1976, p. 35-36).

Unit 4e is interpreted as an allochthonous coal deposited in the channel as a channel filling peat. Coleman (1976, p. 36) states that the late stages of channel filling normally are characterized by a high abundance of peat. There is no indication of soil formation, root burrows or exposure features at Cagle's Mill which would suggest water shallow enough to allow peat accumulation in a marsh.

Unit 4e is transitional between peat accumulation and the deposition of the more siliciclastic unit 4f. Carbonaceous matter is still abundant, composing 65% of the rock, but the clay and quartz content increases. This is interpreted as being caused by a source of terrigenous clastics encroaching close enough to affect the composition of the sediment deposited during periods of high water.

The thinly bedded unit 4f appears to be mainly overbank deposits very strongly influenced by the nearing source of clastics alternating with suspension deposition during low water periods. Some of the thin, continuous beds are lenticular to flaser bedded which, according to Reineck and Singh (1980,, p. 113), form where both mud and sand are available for deposition and periods of deposition alternate with periods of quiesence. These beds sag towards the middle of the channel indicating that the peat in the channel was compacting during the deposition of unit 4f.

Periods of still water alternating with increased flow velocities were commonplace during the deposition of unit 4f as indicated by thin, continuous beds of very fine-grained sandstone alternating with persistent layers of mud and carbonaceous matter (fig. 13). Thinly bedded clay and silt channel fill deposits also are reported from the Brazos River, Texas, by Bernard and Major (1963).

Units 5a and 5b

Unit 5a, unconformably succeeding units 4c, 4d, 4e and 4f is a poorly to lenticularly bedded, gray, fine-grained, lithic, quartz arenite. This unit contains abundant *Calamites* branches and logs and carbonaceous imprints of *Cordaites* leaves. The composition of this rock differs little from that of unit 3, consisting primarily of poorly sorted, medium-, fine-, and very fine-grained subangular quartz grains. Metamorphic rock fragments are moderately abundant. The rock is cemented by secondary quartz and hematite. This unit is laterally discontinuous and generally fills troughs cut into unit 4f. This unit grades vertically into unit 5b.

Unit 5b is thinly bedded, with beds up to 8 inches thick, and is a medium- to fine-grained, red to brown, lithic, quartz arenite. Many layers are micro-cross laminated with carbonaceous films on the bedding planes. The upper bounding bedding planes have complex interference ripples (fig. 14). Beds in this unit are of strikingly constant thickness and persist laterally for 50-75 feet before pinching out. These rocks are mineralogically identical to unit 3 but are finer-grained, moderately well sorted and have a slight fining upward trend in the upper part of the unit.

Environment of Deposistion of units 5a and 5b

The basal sandstone (unit 5a) containing coarse material grading into fine material with abundant plant fossils and resting on a scoured base is like the sequence forming the basal portions of the fluvial sequences described in unit 3. The lack of sedimentary structures within the lower portion indicates rapid dumping rather than systematic deposition in dunes and bars as in unit 3 (Reineck and Singh, 1980, p. 130). The good sorting, fining upward trend, micro-cross laminae and uniform bedding of unit 5b indicate deposition under less severe conditions with decreasing velocity. Complex interference ripples are interpreted by Picard and High (1973, p. 88) as recording changing hydraulic conditions as a flood recedes. Thus units 5a and 5b appear to result from rapid sediment influx and dumping under relatively high conditions followed by systematic velocity decrease producing evenly bedded, fining upward sediments. These units probably represent a small crevasse splay that had a rapid surge of water which transported coarse material. Then, velocity decreased, the flood waned and the crevasse was repaired. Crevasse deposits are described as "fine-grained sandstone, flat bedded or with micro-cross laminations containing sufficient vegetable detritus. . . to impart a dark gray color to certain bedding planes." ". . . more extensive and less variable than channel type sands." by Wanless *et al.* (1970, p. 221). These sandstones at the Cagle's Mill cut are virtually identical to those described in this (notably brief) description.

Units 6a, 6b and 6c

Unit 5b abruptly grades into unit 6a. A 2 inch thick sandy layer marks the contact and, inasmuch as unit 6a is predominantly gray shale, it is likely that this is reworked material. Thus the two units do not represent continuous deposition.

Unit 6a consists of 6 feet of silty, fissile, gray shale with very fine-grained sandstone and siltstone lenses and layers 1/64 to one inch thick. The finer-grained lenses are much more abundant. Lenticular sideritic concretions are widespread. Petrographic analysis of one of these concretions reveals layers of coarse grained material, mostly angular, fine-grained sand and silt sized quartz, some oriented parallel to bedding, metamorphic rock fragments and planar bedded muscovite alternating with layers of clay-sized material with sparse angular quartz silt. These layers are planar bedded.

Bioturbation derived round siderite concretions are 1/8-1/4 inch in diameter. Unit 6a gradually grades into unit 6b.

Unit 6b is 3 feet of fine-grained, white, lithic, subangular quartz arenite. Beds are up to 2 inches in thickness. The sandstone is approximately of the same composition as that of unit 3, differing mainly in the lack of hematite cement. The sandstone is interbedded with thin-bedded sandstone.

The sandstone is micro-cross laminated. Burrowing has produced rounded iron stained masses 1/8-1/4 inch in diameter. Unit 6b grades into unit 6c.

Unit 6c is 6 inches of fine-grained, white, quartz arenite with a clay mineral matrix. The unit is heavily bioturbated on its upper surface (fig. 15) and lacks internal structure. It is composed of 85% fine-grained sand to silt-sized subangular quartz. Much of this quartz floats in a detrital clay mineral matrix comprising about 10% of the rock. Schist fragments constitute about 2% of the rock. Accessories include plagioclase, chert, metaquartzite, zircon, muscovite and potassium feldspar. Unit 6c is the uppermost Pennsylvanian unit exposed in the area and is unconformably overlain by unit 7, a Pleistocene till.

Environment of Deposition of Units 6a, 6b and 6c

The fine-grained detrital coarsening upward sequence of unit 6 is inferred to be deposited by a thin, prograding deltaic lobe. The total thickness of unit 6 is only 10 feet but many of the coarsening upward Pennsylvanian deltaic sequences are notably thin because they were deposited in a shallow cratonic sea (Klein, 1980, p. 107-108; Wanless *et al.*, 1970, p. 224). The gradation from shale to sandstone represents transition from distal deltaic deposits to sediments deposited near the distributary mouth. The distributary depositing sands into the area need not have been extremely near by. The sediments carried by these rivers may merge laterally into one another forming thin sheet sands near the front of the deltaic lobe (Coleman, 1976, p. 14). This may explain the lack of an erosional basal contact as observed below in unit 3.

Units 7 and 8

Units 7 and 8 are Pleistocene loess and till deposits separated by a paleosol between them. These units are not described here but have been described in detail by Wayne (1958, p. 10).

CONCLUSIONS

Depositional History of the Pennsylvania Sequence Exposed at the Cagle's Mill Spillway

The lowest rocks exposed in this sequence were deposited as muds and silts falling out of suspension at the front of a delta prograding into a shallow marine environment. Organic content of the sediments generally remained high but upon occasion were depleted, allowing increased biologic activity in the sediments. Rare, exceptionally high velocity surges of the delta front scoured the bottom and brought relatively coarse material into the area, such as the sediments composing the rocks of units 2a and 2b.

Shallow cratonic seas are characteristic environments of the Pennsylvanian eastern midcontinent (Blatt *et al.*, 1980, p. 688; Wanless *et al.*, 1970, p. 239; Pryor and Sable, 1974, p. 313) and it is likely that these sediments accumulated in such a sea. Distal deltaic deposits in shallow environments build up above the level of the bottom of distributaries delivering the sediment. This causes unconformable contact at the base of prograding distributary sediments (Donaldson *et al.*, 1970, p. 107; p. 116). Progradation of an extensive generally south flowing, distributary system, cut into the earlier distal muds delivering the sand now observed as unit 3. These abundant sand deposits were deposited on a deltaic plain (Wanless *et al.*, 1970, p. 224).

Channel avulsion or lobe abandonment caused desertion of the principal channel observed in the Cagle's Mill spillway. The tractional load being carried was deposited immediately as unit 4a followed by deposition of the suspended load, unit 4b, in still, oxygenated water. Furthur suspension deposition under increasingly stagnant conditions produced the black shale of unit 4c. With the deprivation of any active source of clastics little detritus was available to fill the channel except for transported organic debris (Coleman, 1976, p. 35) which filled the channel with peat. The peat, constantly compacting under its own weight, provided a low area where sedimentation continued.

The approach of a new source of clastic material on the delta plain, possibly caused by lobe reactivation or more probably a new channel entering the area, produced unit 4e in which the carbonaceous material is diluted with clay minerals and quartz grains. Furthur encroachment of the new clastic source increased the supply of sediment available for channel filling by overbank flow. This increasingly coarse material filled the depression formed by the peat compaction in the old channel. The final channel fill, unit 4f, is composed of overbank deposits alternating with suspension deposits. Accumulation probably also occurred on adjoining areas during periods of flooding.

After the channel was filled rapidly and completely by these processes there was little compaction as bedding in other overlying sediments does not sag in the channel region.

Thereafter crevassing onto the delta plain, possibly from the same nearing distributary system supplying the channel fill laid down units 5a and 5b.

Rapid subsidence allowed the area to become submerged quickly with a minimum of reworking of the upper beds. Thereafter a small delta or subdelta prograded into the newly formed bay, producing the coarsening upward sequence of units 6a, 6b and 6c. Absence of a unit consisting primarily of shale or clay indicates that this area was not far removed from a sediment source. The gradational nature of this deposit as well as the abundant clay material in the uppermost sandstone indicates that the spillway area was near but not immediately in front of a prograding distributary. Being distal to the prograding bar this environment would probably be best described as the bar front of Klein (1980, p. 101). Sediments deposited in this environment consist of sand and silt dispersed from the mouth of an active distributary.

In summary the following sequence of environments is represented at the Cagle's Mill spillway.

1. Delta front
2. Delta Plain-fluvial distributary
3. Delta Plain-flood deposition
4. Shaly Prodelta
5. Sandy and Silty Delta front
6. Sandy Bar Front

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Figure Captions

Fig. 1. Schematic representation of stratigraphy and lithologies on the north wall of the spillway. Numbers correspond to those in text.

Fig. 2. Exposure of Pennsylvanian sequence on the north wall of the spillway. Numbers correspond to numbering scheme of figure 1 and in text.

Plate 3.

Fig. 3. orbiculoid brachiopod collected from unit 1a, x8, bar scale equals 5mm.

Fig. 4. unit 2a, x80, uncrossed polars, bar scale equals .5mm.

Fig. 5. unit 2b, x80, uncrossed polars, bar scale equals .5mm. Note laminated appearance, shale intraclast.

Figs. 6, 7. Unit 3, thick bedded (6) and thin bedded (7) subunits, x80, crossed polars, bar scale equals .5mm. Note difference in size and high degree of sorting.

Fig. 8. depositional sequence, unit 3. The lowermost unit is approximately 5 feet thick.

Fig. 9. paleocurrent data, unit 3, single dots are poles to crossbeds, double headed arrow is current ripple trend and single headed arrows are indicated paleocurrent direction.

Plate 4.

Fig. 10. intraclast in lower subunit of unit 3. Intraclast is approximately 7.5cm in diameter.

Fig. 11. unit 4e, x20, uncrossed polars, bar scale equals .5mm.

Fig. 12. unit 4f, x20, uncrossed polars, bar scale equals .5mm.

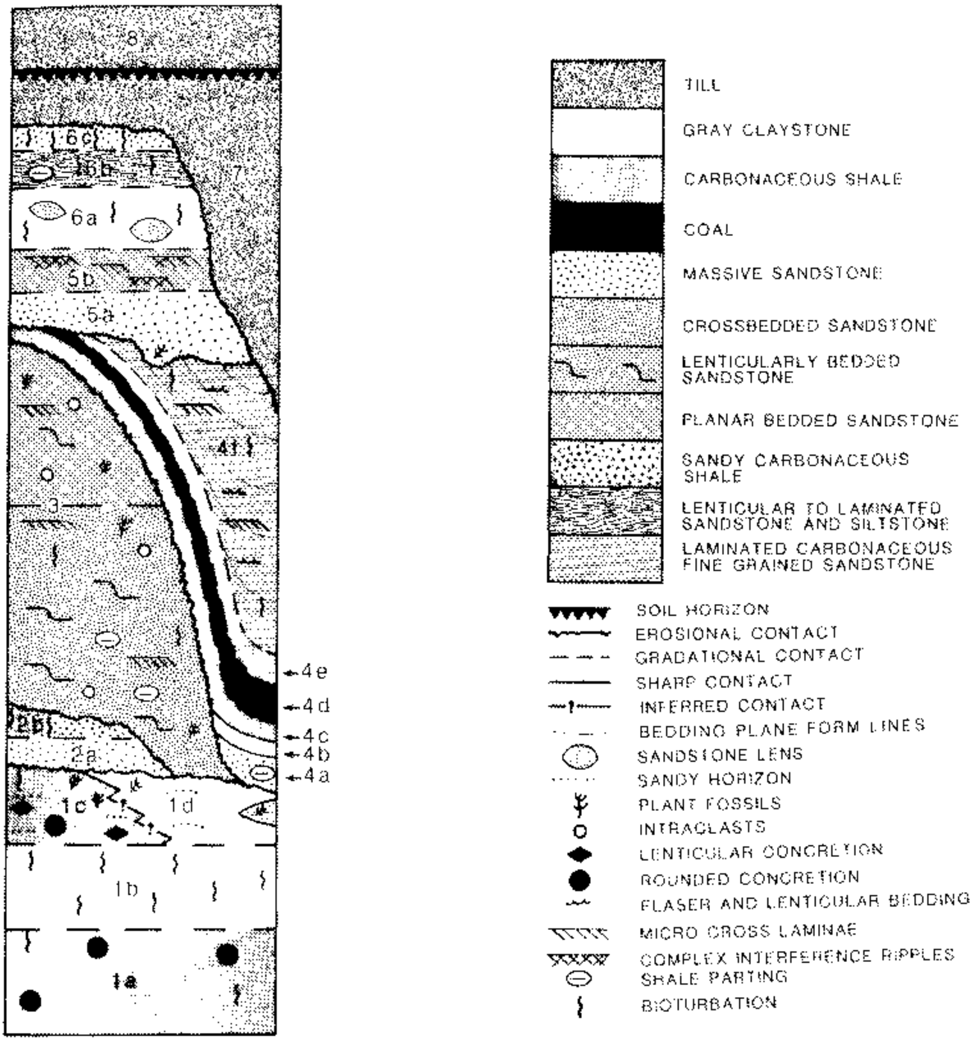
Fig. 13. macroscopic appearance of unit 4f. Note thin, even bedding.

Fig. 14. complex interference ripples of bedding surface of unit 5b.

Fig. 15. heavily bioturbated bedding surface of unit 6c.

SCHEMATIC STRATIGRAPHIC RELATIONSHIPS OF THE NORTH WALL OF THE CAGLE'S MILL SPILLWAY

FIGURE 1



PENNSYLVANIAN EXPOSURE ON THE NORTH WALL OF THE CAGLE'S MILL SPILLWAY

Figure 2

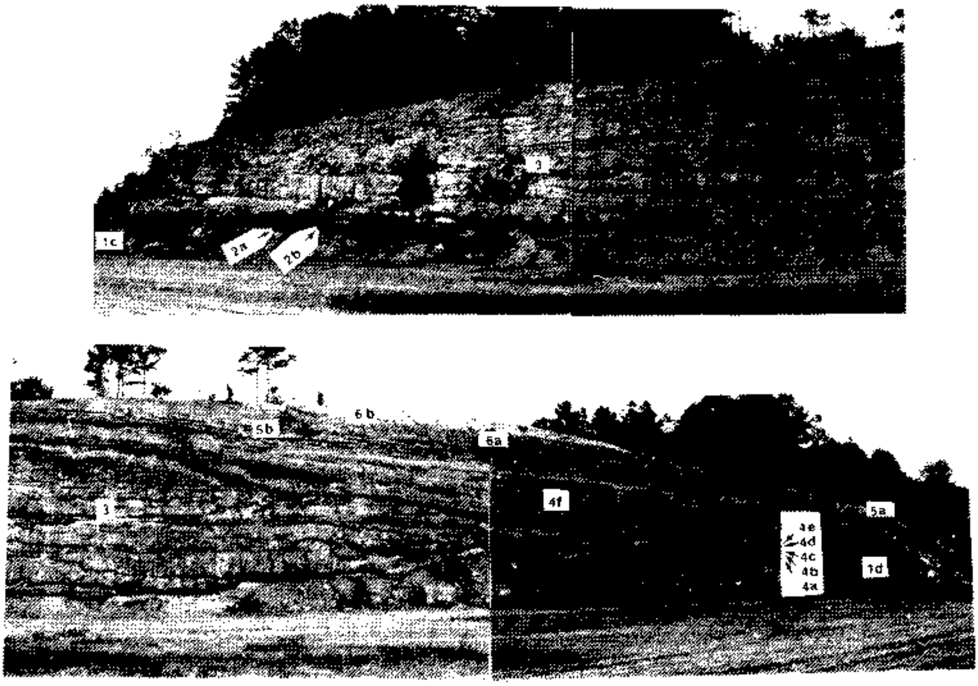
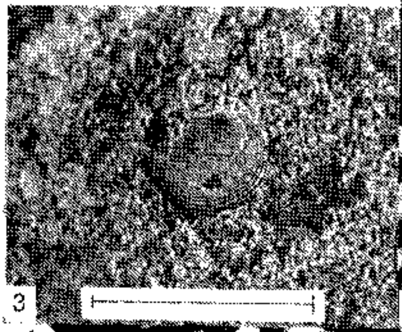


Plate 3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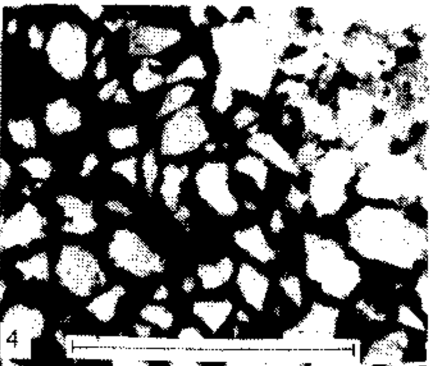
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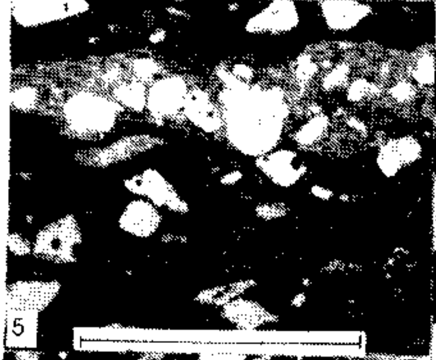
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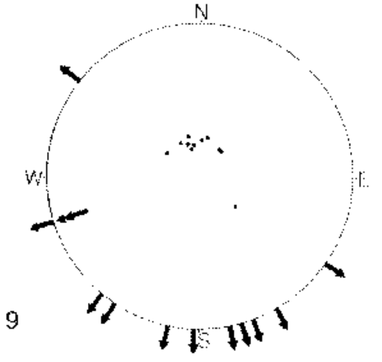
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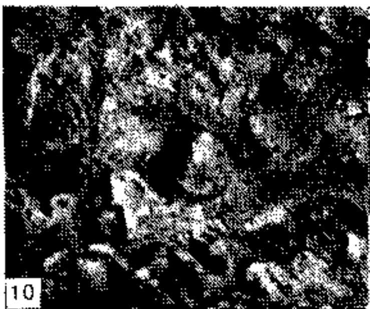
Plate 4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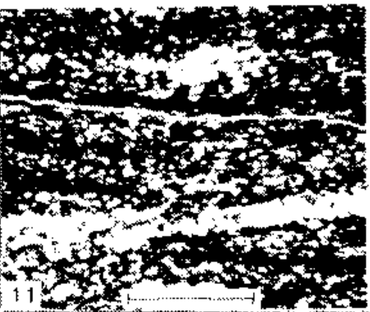
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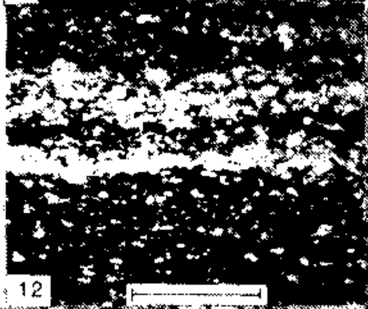
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