A STUDY OF MINE DRAINAGE QUALITY AND PREDICTION USING OVERBURDEN ANALYSIS AND PALEOENVIRONMENTAL RECONSTRUCTIONS, FAYETTE COUNTY, PENNSYLVANIA[1]

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Abstract.--The Stony Fork watershed is a 7.44-mi^2 drainage basin in Fayette County, PA. Geologic investigations during the late 1970's established that surface mining in the watershed was largely limited to the Upper Kittanning coal seam. Interpretations of drill logs and field work has shown the Upper Kittanning and its overburden were deposited in an upper delta plain environment. This environment is marked by lateral variability and abrupt facies changes. This variability affects the distribution of calcareous materials, which is evident in acid-base account overburden data, and in the water quality associated with individual mine sites. Some mines are producing alkaline water while others are producing acid mine drainage. In addition to the paleo-environmental controls on the distribution of calcareous strata, it was found that all overburden holes less than 40 ft. to the base of the Upper Kittanning coal lacked calcareous material. This absence is attributed to weathering. Sulfur on the other hand persists even at very shallow cover. Mine drainage quality is related to the presence or absence of calcareous rocks. Surface mining in areas devoid of calcareous rocks due to nondeposition or weathering has resulted in acid mine drainage. Mines developed in areas of abundant limestone produce alkaline water.

INTRODUCTION

The Stony Fork watershed, a 7.44-mi^2 drainage basin, is located in the Fort Necessity quadrangle in southern Fayette County, Pennsylvania. It is classified as a High Quality stream according to Pennsylvania Department of Environmental Resources (DER) Rules and Regulations and has been afforded special protection status since the early 1970's. Because of this status, a large amount of hydrologic and geologic information has been obtained from the applications for surface mines. Initially, these data were difficult to interpret. Results of overburden and water quality testing from mine sites in close proximity showed considerable variability. These differences were at first attributed to the presence of several coals in the area having dissimilar overburden characteristics. However, attempts at correlating these coals became very confusing. It soon became apparent that a much better understanding of the basic geology of the area was needed.

This was clearly understood by the late 1970's when Pennsylvania's Bureau of Forestry and Bureau of Topographic and Geological Survey were working in the area to develop an estimate of coal resources. In order to resolve the coal correlation problems, a series of deep exploration core holes were drilled. The cores were examined in detail, with special care given

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to identifying the key beds in the stratigraphic succession, ranging from the Conemaugh Group marine beds downward to the Mauch Chunk Formation red beds. As a result, an accurate stratigraphic framework was developed and a better understanding of the sedimentological characteristics of the area was achieved. It became evident that: (1) surface mining in the Stony Fork watershed is generally limited to a single coal seam, the Upper Kittanning; and (2) the variability of mine drainage, both alkaline and acid within a relatively short distance, is due to complex lateral changes in the Upper Kittanning overburden. This study attempts to relate the geologic features of the area to the quality of water produced during mining. It is hoped that a better understanding of these relationships will enhance predictability of potential problem areas and aid in preparation of future surface mining plans.

METHODS

Forty test holes used for overburden analysis were obtained from the Bureau of Mining and Reclamation (BMR) surface mine permit files. The overburden from these holes was analyzed using the acid-base accounting method (Sobek and others, 1978) which identifies potentially acid and alkaline producing strata. Figure 1 shows the distribution of the overburden drill holes as well as the five most recent areas of mining within the watershed. Areas A through D have acid-base account overburden data. Area E does not have acid-base account overburden data, but the geology has been studied in detail and it is included because of its proximity to the other mine sites.

Values for calcium carbonate equivalent and percent total sulfur were obtained from the overburden analysis test holes. The neutralization potential (NP) values for each sample were weighted according to thickness of each interval. These values were then multiplied by the weight of the sample stratum per acre foot. The resulting value for each hole is in terms of tons $CaCO_3$/acre. Likewise the maximum potential acidity (MPA) data were summed giving tons $CaCO_3$/acre deficiency for each drill hole. The traditional "excess" and "deficiency" (net NP plus MPA) as described by Sobek and others, 1978, were not used in this study. Included in the calculations were all overburden strata above the coal and one ft of the strata immediately below the coal. Coals were not included. Eight of the holes at Site A had NP determined on only those strata that "fizzed" when dilute hydrochloric acid was applied. Experience

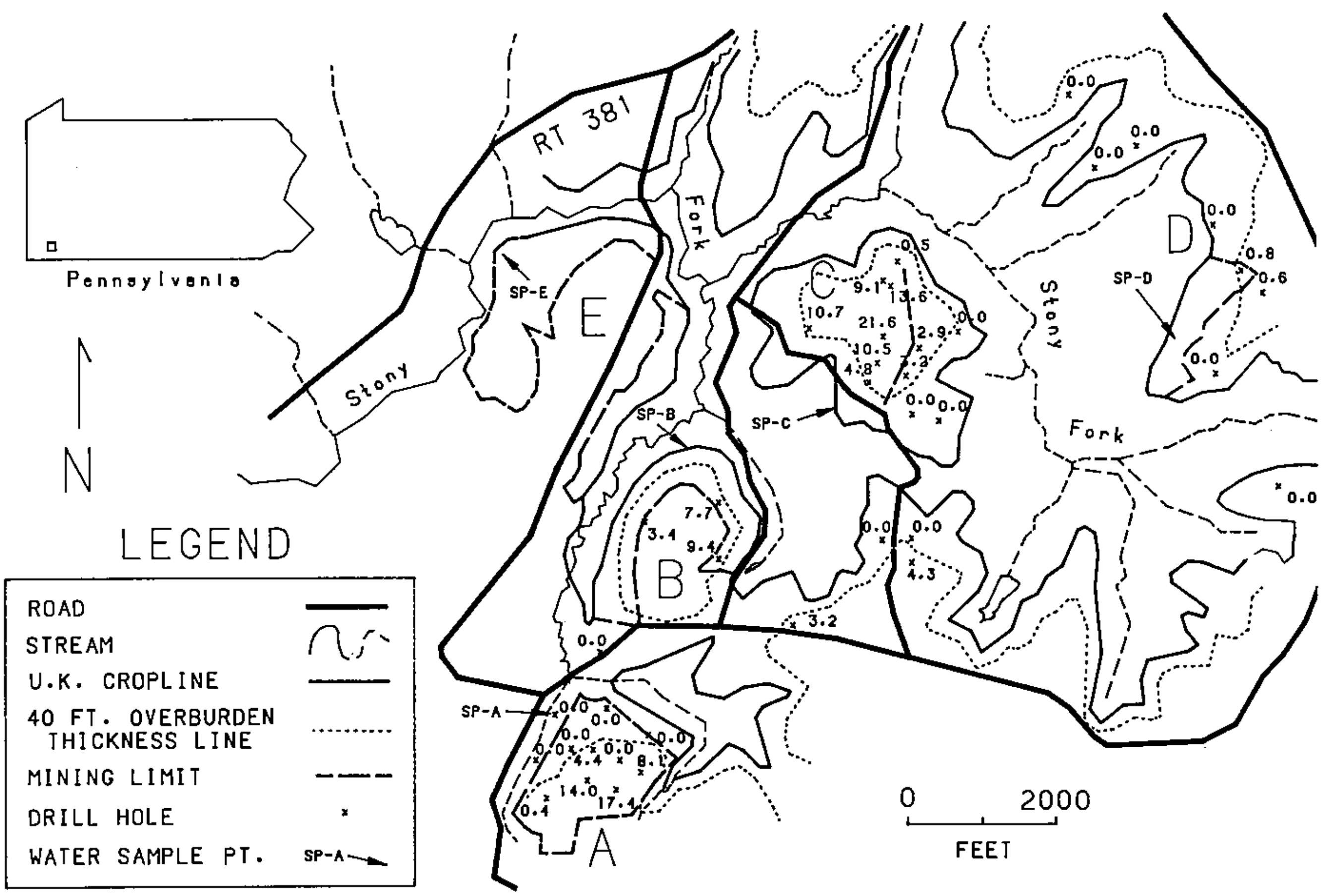

Figure 1.--Map of study area showing overburden analysis drill hole locations and associated mine sites (A through E). The numbers beside the drill hole locations indicate the amount of calcareous material in the hole presented as thousands of tons of $CaCO_3$ per acre. Note that all holes outside the 40 foot cover line have 0.0 amount of calcareous material.

has shown that rocks with NP's less than 30 do not normally exhibit a fizz, whereas rocks with NP's greater than 30 normally do. In order to include all data in our calculations and to make the data internally consistent, only NP's greater than 30 with a fizz were used. Experience has shown that NP's less than 30 do not generally contribute significant alkalinity and total sulfur values of less than 0.5 percent often do not result in poor quality water. Only sulfur values greater than 0.5 percent and neutralization potentials greater than 30 tons $CaCO_3$/1000 tons were used in the calculations. A comparison between these data versus data including all NP and sulfur values yielded similar results.

Water sample data used in this study were obtained from BMR permit files. The analyses include both BMR samples and company monitoring data.

Geologic cross sections and isopach maps were constructed to determine the thickness distribution and lateral and vertical relationships of the various rock units in the area. Additionally, a series of maps was drawn showing the areal distribution of rock types at different stratigraphic levels. These slices through the strata at arbitrary vertical positions are intended to show successive patterns of sediment deposition occurring throughout the area at different instances of time. This method of recreating contemporaneous depositional environments is an approximation. Differences in compaction of dissimilar sediments, downcutting of stream channels and original topographic relief are factors which distort precise time line reconstructions.

A wide range of types of data was used for developing the geologic cross sections and maps. Reliability of information used was generally very good. Most of it consisted of geologists' descriptions of cored exploration drill holes, overburden test hole logs, and surface mine highwalls. This was supplemented by the somewhat less reliable descriptions of rock cuttings from air rotary drill holes submitted with mining permit applications. The data points used in the construction of cross-sections, isopach maps and lithology distribution maps are shown in figure 2.

GENERAL GEOLOGY

The stratigraphic section examined in this study consists of the stratigraphic interval from 20 ft below to 100 ft above the Upper Kittanning coal. It ranges from the calcareous rocks associated with the Johnstown limestone at the bottom of the section, to the rocks overlying the Upper Freeport coal horizon at the top (figs. 3 & 4). The prominent feature throughout this section is the laterally discontinuous nature of the rock units. Correlation of these units is difficult, and an essential first step in understanding their lateral

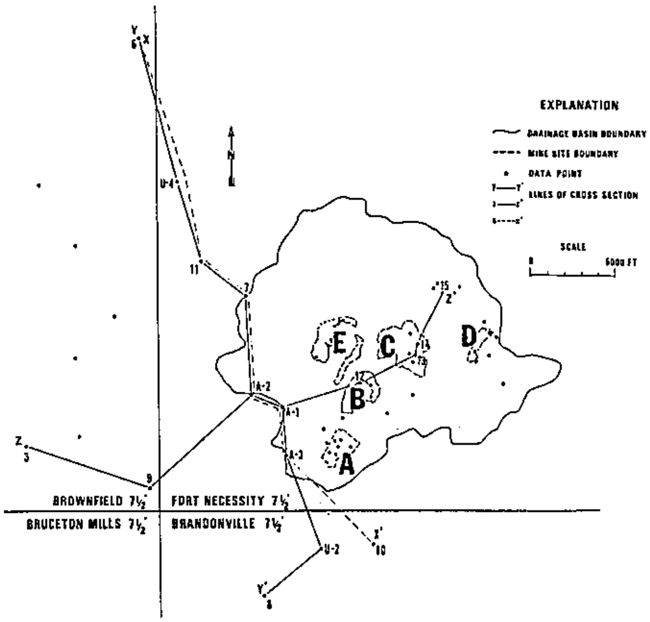

Figure 2.--Data and section line location map. Bold letters (A-E) designate mine sites discussed in text.

relationship is construction of a stratigraphic framework. This was accomplished by correlating the persistent marine zones found in the lower part of the overlying Conemaugh Group. The Brush Creek, Pine Creek, and Woods Run marine zones are persistent throughout the area and were recognized in every drill hole that penetrated their horizons (fig. 5). The first red beds encountered in the upper part of the Mauch Chunk Formation also provided useful stratigraphic control from below.

Sedimentologically the prominent features in this study are the Upper Kittanning coal, a sandstone overlying the coal, and several calcareous beds. The Upper Kittanning Coal is generally thick and continuous over most of the area (fig. 6). Several splits of the coal are apparent in section Y-Y' (fig. 3). One occurs in the area of holes 7 and 11. The coal here is split by a sandy siltstone wedge which becomes thicker and coarser to the west. On the southern end of section Y-Y' (Hole 8) a 2.5-ft argillaceous limestone parting in the coal suggests splitting in a southward direction.

The sandstone overlying the coal in the western part of the drainage basin has a lenticular, elongate shape. The thicker part of this lense is approximately a mile wide in the south and narrows to less than a half mile wide northward (fig. 7). The sandstone is coarse-grained at the base and becomes fine-grained upward. The thick, main body of the sandstone grades laterally into thin, very fine-grained sandstones interbedded with sandy silt shales, silty clay shales, and calcareous silty claystones.

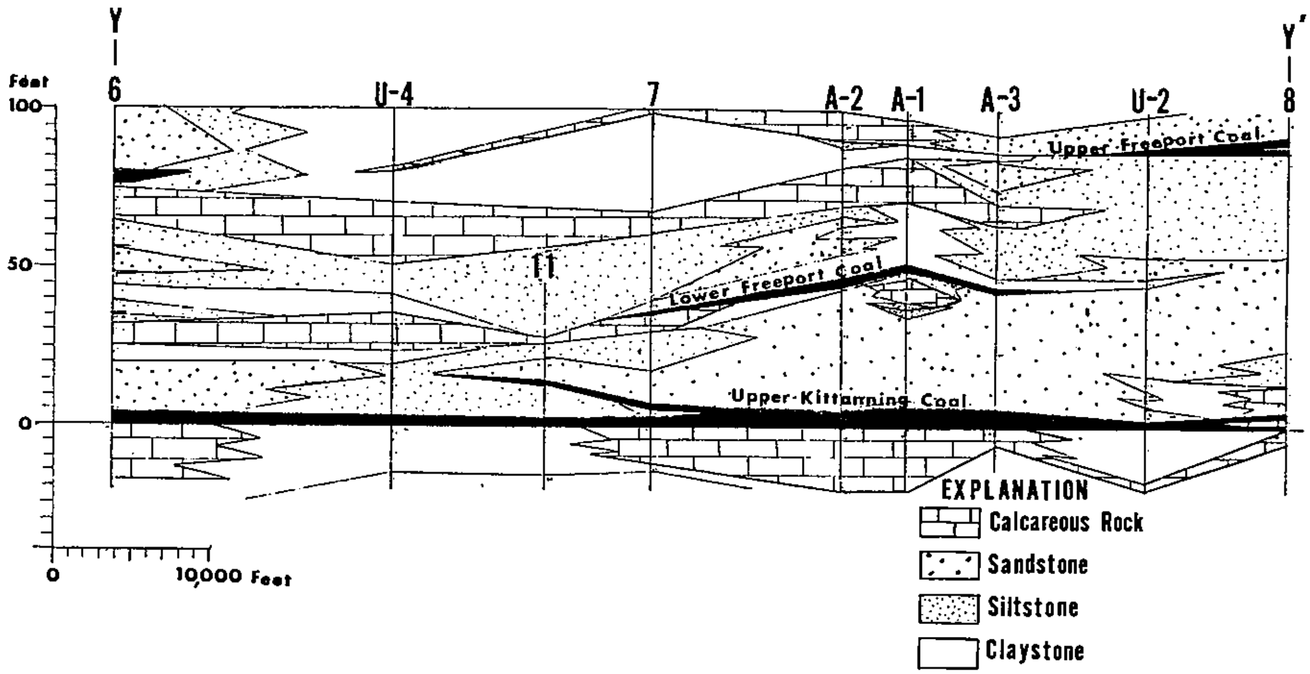

Figure 3.--Stratigraphic cross section (Y-Y') of the Upper Kittanning to Upper Freeport interval.

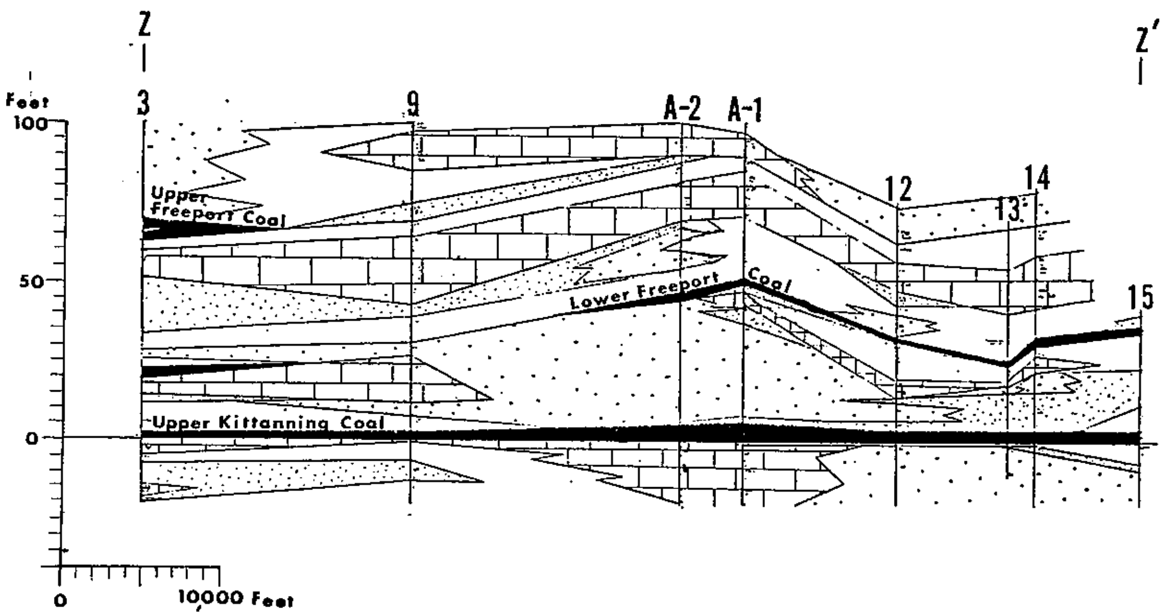

Figure 4.--Stratigraphic cross section (Z-Z') of the Upper Kittanning to Lower Freeport interval.

This part of the section also has three, discrete, major calcareous zones. These zones often contain argillaceous limestones and contain freshwater fossils (Spirorbis and ostracodes). The most persistent and thickest of these is beneath the Upper Freeport coal horizon approximately 50 to 80 ft above the Upper Kittanning coal (figs. 3 & 4). Another thick but discontinuous zone is present below the Upper Kittanning in the western part of the area. This calcareous zone attains a maximum thickness of 25 ft and usually contains the argillaceous Johnstown limestone. The area where the limestone is thickest and least argillaceous coincides with the thickest development of the Upper Kittanning coal and overlying sandstone. South of the Stony Fork drainage basin this calcareous zone appears to be laterally equivalent to the Upper Kittanning coal. Limestone in drill hole 8 is found directly below and above the coal and forms a thick parting in the coal itself (fig. 3). A few small isolated pods of limestone directly on top of the coal were encountered at other locations in and around the basin. A third major calcareous zone is situated approximately 15 to 40 ft above the Upper Kittanning coal. Its position varies from just below the Lower Freeport coal horizon to midway between the Lower Freeport and

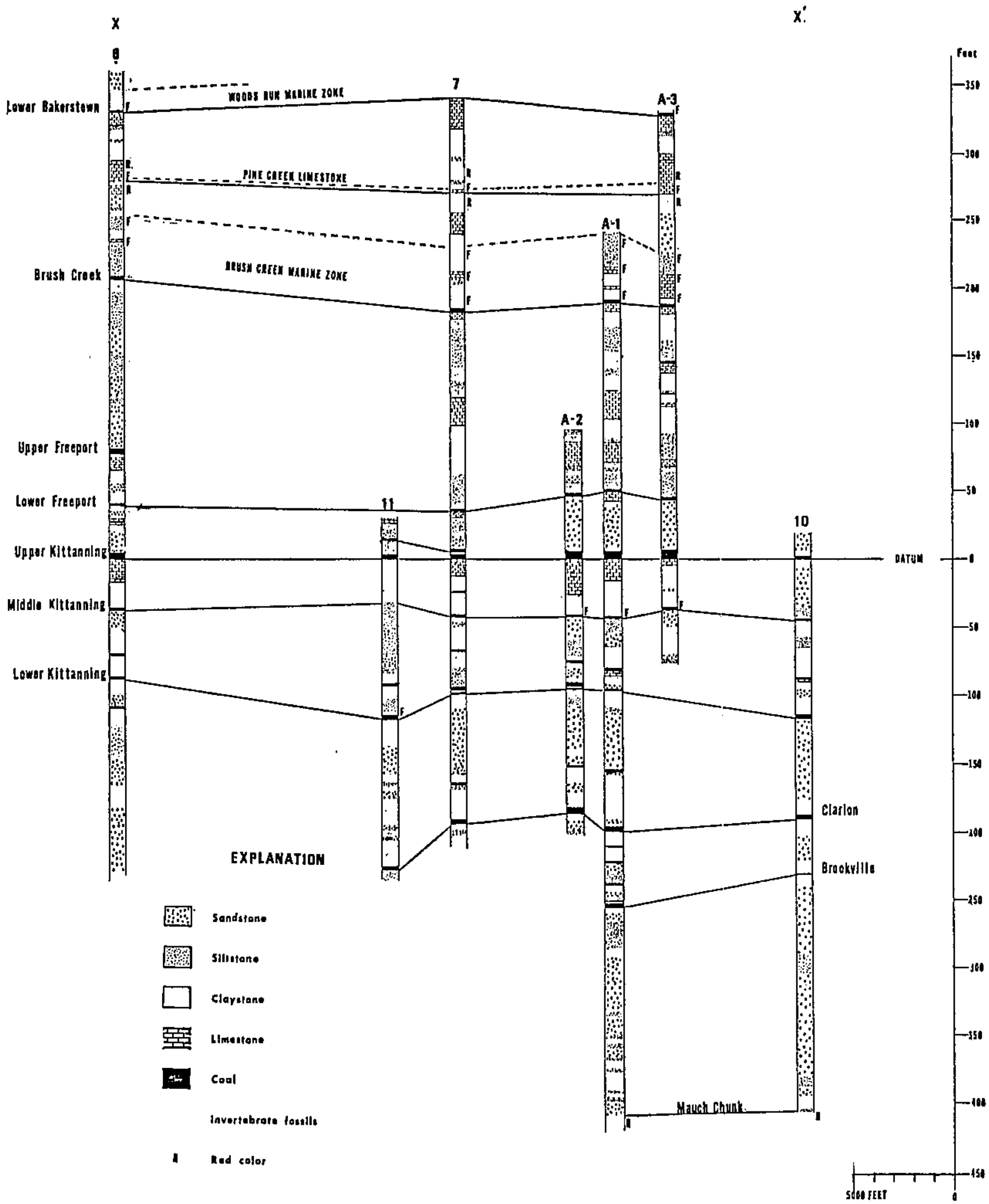

Figure 5.--Stratigraphic cross section of the Mauch Chunk Formation to Lower Bakerstown coal interval. See figure 2 for location of section.

Upper Kittanning.

In addition to the well-developed Upper Kittanning coal, two other coals of minor significance are present in and around the drainage basin. The Lower Freeport coal has a sporadic distribution in the study area. It reaches a maximum thickness of 2 to 3 ft, but is thin to absent over much of the area. The Upper Freeport coal is rarely present in the study area. Carbonaceous clay shales, calcareous claystones, and argillaceous limestones containing fossil ostracodes and Spirorbis often occupy its horizon.

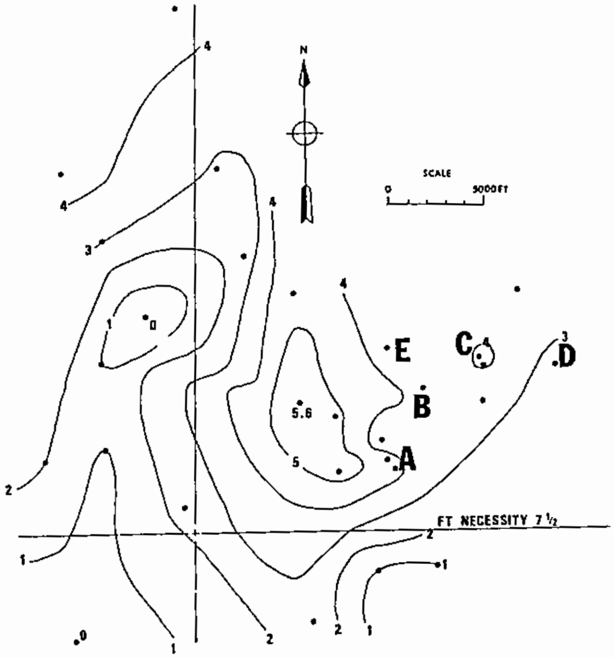

Figure 6.--Thickness map of the Upper Kittanning coal. Thickness lines given in feet.

PALEOGEOGRAPHY

The map showing distribution of lithologies 1 ft below the Upper Kittanning coal indicates the presence of a large body of sandstone in the eastern portion of the study area (fig. 8). Not enough information is present to determine its gross geometry, however a few deep holes indicate that the sandstone which is as much as 40 ft thick grades upward from coarse to very fine-grained. It is adjacent to a narrow belt of claystone to the west which separates the sandstone from a large area of calcareous claystone and argillaceous limestone containing fossil freshwater invertebrates. These calcareous deposits are indicative of a freshwater lake or pond environment. The narrow belt of claystone and adjacent very fine grained upper part of the sandstone body suggest the presence of overbank deposits flanking a levee and stream channel system to the east.

This period of time appears to be followed by a nearly complete cessation of deposition over the entire study area, and the subsequent development of luxuriant vegetation of the Upper Kittanning peat swamp. Some local ponding of water too deep to sustain vegetation occurred in the swamp complex. This resulted in the formation of the limestone partings seen in several places. The coal split located in the area of drill holes 7 and 11 may indicate the presence of a brief very local incursion of sediment into the peat swamp from the north-west (fig. 3). Closer spacing of drill holes is needed in this area to better understand this minor episode of deposition.

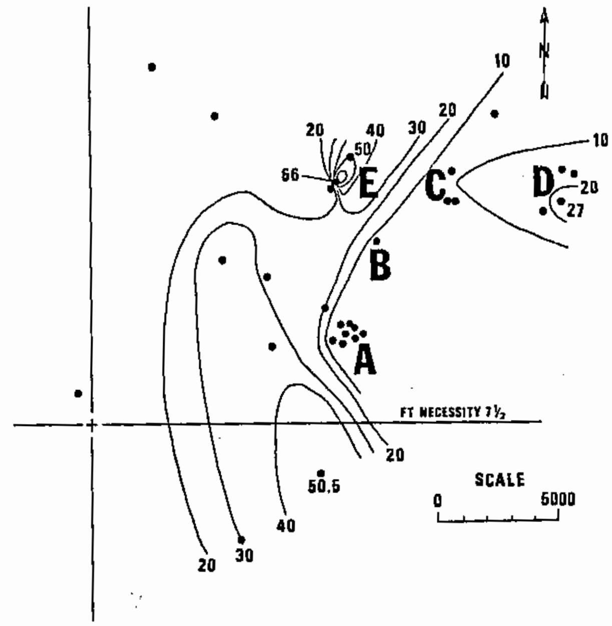

Figure 7.--Thickness of the sandstone above the Upper Kittanning coal. Thickness lines given in feet.

Distribution of lithologies 10 ft and 25 ft above the coal provide a good look at the nature of the sediment influx which terminated Upper Kittanning peat development (figs. 9 and 10). Initially a blanket of sand and silt was deposited over the peat throughout most of the area. A fluvial channel oriented roughly north-south (fig. 7) and associated levee deposits were soon established in the area underlain by the thickest coal and limestone. In the early stages of sediment influx over the peat swamp this area of thick peat would probably have undergone the most compaction and would have quickly localized the channelway. As a result,

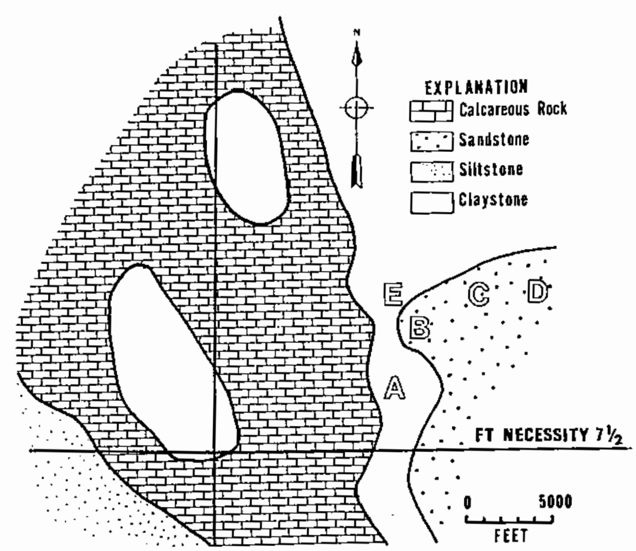

Figure 8.--Distribution of lithologies one foot below the Upper Kittanning Coal. Letters designate mine site locations.

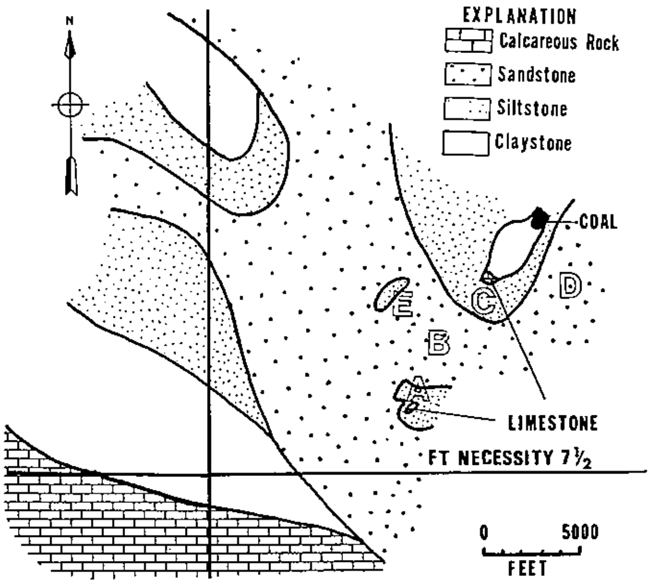

Figure 9.--Distribution of lithologies 10 feet above the Upper Kittanning coal. Letters designate mine site locations.

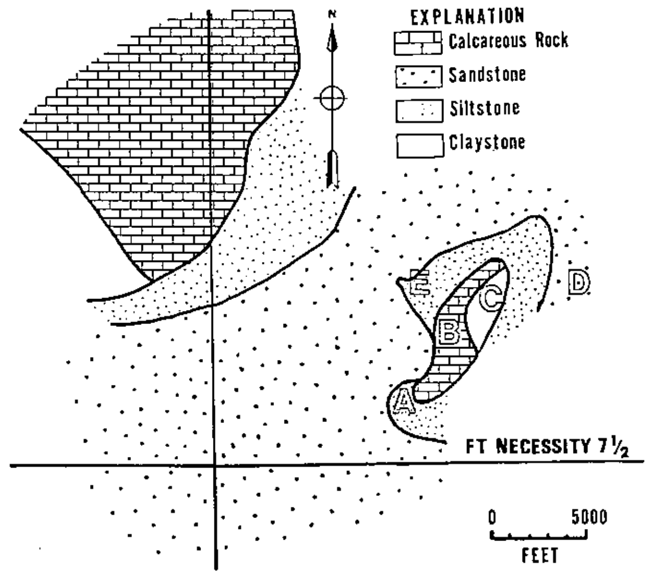

Figure 10.--Distribution of lithologies 25 feet above the Upper Kittanning coal. Letters designate mine site locations.

ponded overbank areas of very low energy were established soon after flooding of the swamp. Calcareous claystones, such as the ones found in the overburden of mine sites A and C were being deposited in close proximity to the high energy channel system (fig. 9). The area between mine sites A and C just to the east of the channel developed into a persistent site of low energy (figs. 10 and 11). By the time the sediments 50 ft above the coal were deposited the main channel area appears to have lost much energy and become very narrow (fig. 11). The major episode of ponding which was to cover the entire area with calcareous deposits by Upper Freeport time, was just beginning in the western part of the study area.

The map of rock distribution 10 ft above the coal shows an area in the northeastern part of the Stony Fork watershed in which thin coal is present (fig. 9). This is an area where considerable splitting of the Upper Kittanning coal has been observed in mining. It is just west of an area containing relatively thick very coarse grained sandstone with some granular size grains. This could indicate the presence of a channel system contemporaneous with the peat swamp to the east. This channel system may be related to the sandstone body found directly under the coal in the eastern portion of the study area (fig. 8).

In summary, considering the relatively narrow width of the stream channel system and adjoining levees, and the preponderance of freshwater lake and pond sediments throughout the section, this area was most probably part of an interdistributary area of an upper delta plain during Upper Kittanning to Upper Freeport time. Except for some clays, these areas received little sediment input; as a result aggradation could not keep up with subsidence, and small water bodies were formed. The development and enlargement of these ponds drowned out the peat-producing marshes and swamps. Streams carrying a sandy bed load in this type of environment can be expected to be small and sinuous (Frazier and Osanik, 1969). As a result patterns of deposition within this environment are complex with many lateral changes.

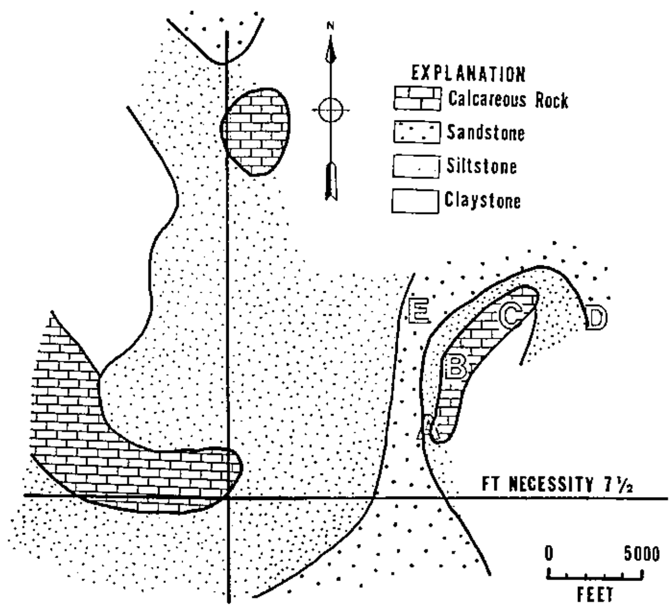

Figure 11.--Distribution of lithologies 50 feet above the Upper Kittanning coal. Letters designate mine site locations.

DISTRIBUTION OF NEUTRALIZATION POTENTIALS AND SULFUR AS THEY RELATE TO WEATHERING

In this area there is a weathering profile to a depth of 20 feet below the surface which has selectively affected the calcareous rocks and pyrite concentrations of the Upper Kittanning overburden in the study area. Field observations and drilling records have reported brown to orange coloration of the rocks and soil in this interval. The effects of weathering on $CaCO_3$ can be seen in the NP data gathered for the study area. A plot of the NP data in terms of tons $CaCO_3$ per acre ft versus thickness of overburden on the Upper Kittanning coal seam in figure 12 clearly shows a $CaCO_3$ threshold at a thickness of about 40 ft. Holes that encountered less than 40 ft of Upper Kittanning overburden lack calcareous material. Holes that penetrated more than 40 ft of Upper Kittanning overburden show a wide range of values, from 0 to hundreds of tons $CaCO_3$/acre ft. There are two reasons for this. In the first place, test holes in the study area show that significant occurrences of limestone are usually found 20 ft or more above the Upper Kittanning coal seam (figs. 3 & 4). In the second place, weathering has leached all the carbonate material to a depth of 20 ft below the surface. Because of these two factors, more than 40 ft of Upper Kittanning overburden is required before any measurable amounts of $CaCO_3$ can be found. If the effects of weathering were eliminated overburden thicknesses of only 20 ft could have calcareous material present. Figure 13 is a plot of sulfur versus thickness of Upper Kittanning overburden (sulfur is expressed in terms of tons $CaCO_3$ deficiency/acre ft). Unlike the calcareous material, the sulfur data shows no overburden thickness threshold. Sulfur greater than 1.0 percent was present at depths of only 10 to 15 ft below the surface. It appears that weathering of $CaCO_3$ is more complete than weathering of pyrite at shallow depths. Therefore, areas within the Stony Fork watershed with less than 40 ft of overburden will lack calcareous material, but still potentially have high sulfur concentrations.

Figure 12 shows that when there is more than 40 ft of overburden there is a wide range in available alkaline material. We attribute this to the regional and patchy distribution of freshwater limestone and occasional fluvial channels cutting out and replacing the limestone with non-calcareous rocks.

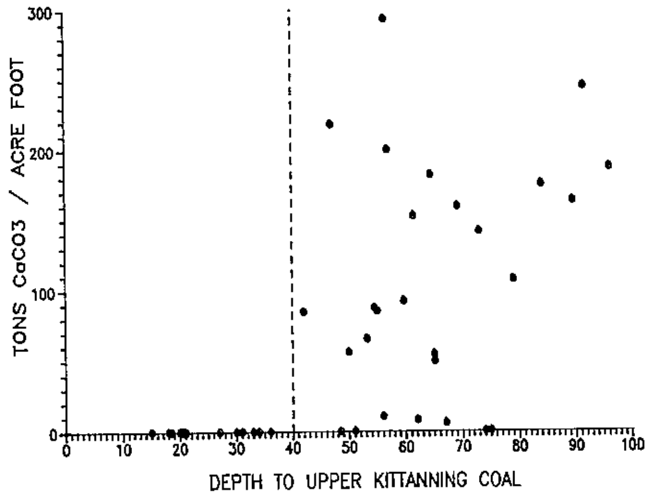

Figure 12.--Graph showing relationship between calcareous material per acre foot and depth to bottom of Upper Kittanning coal. calculations were made based on neutralization potentials above 30 tons/1000 tons.

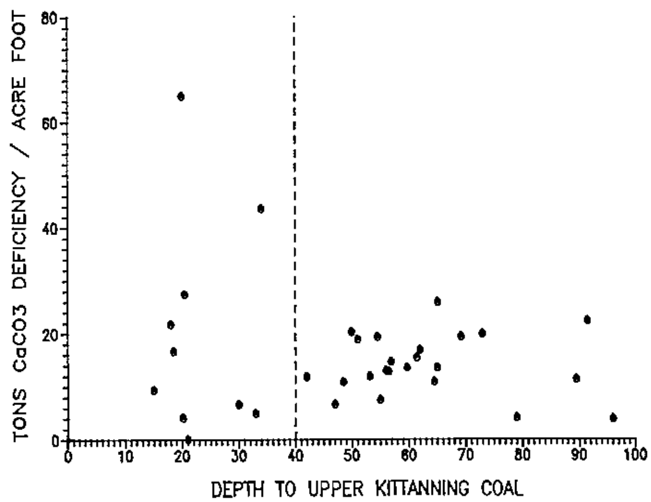

Figure 13.--Graph showing relationship between potentially acid producing strata and depth to bottom of Upper Kittanning coal. Calculations were made based on sulfur values above 0.5%.

WATER QUALITY OF MINE SITES

In each of the five mine sites studied (A through E) the Upper Kittanning coal was the principal seam of interest. The Lower Freeport coal horizon was also encountered at each site but generally appeared as a thin coal or a carbonaceous shale except at site C where it reached a minable thickness. Calcareous rocks where present consisted of either argillaceous limestone or claystone with limestone nodules. The maximum highwall heights ranged from a low at site D of 45 ft to a high at sites A and C of 90 ft.

Determinations of water quality were made on pit water samples taken during mining, and on water from crop springs, monitoring wells, and spoil seeps taken both during and after mining. These samples were analyzed for pH, alkalinity, acidity, iron, manganese, aluminum, and sulfate. Summaries of selected parameters are shown in tables 1 and 2.

TABLE 1. -- PIT WATER DURING ACTIVE MINING

Mine Site	N	pH			Net Acidity[1] mg/l			Sulfate mg/l		
		Med.	Q1[2]	Q3	Med.	Q1	Q3	Med.	Q1	Q3
A	14	6.7	6.2	7.0	-68	-85	-34	101	43	166
B	6	6.0	5.4	6.6	16	-15	59	17	6	29
C	2	7.2	7.1	7.3	-154	-224	-84	79	59	99
D	19	3.0	2.0	3.1	406	250	1028	630	420	900
E	9	3.3	3.1	3.8	158	65	194	380	250	592

[1]Net acidity = acidity - alkalinity. Negative number indicates net alkalinity.
[2]Q1 and Q3, upper and lower quartilies determined by sorting.

TABLE 2. -- POSTMINING WATER QUALITY

Sample Point	N	pH			Net Acidity[1] mg/l			Sulfate mg/l		
		Med.	Q1[2]	Q3	Med.	Q1	Q3	Med.[3]	Q1	Q3
SP-A					see figure 14 graph					
SP-B	4	5.6	5.5	5.8	6.0	0.2	11.8	<43	-	-
SP-C	7	6.0	5.7	6.3	-4	-34	4	<40	-	-
SP-D	9	3.2	3.0	4.2	456	293	609	918	756	1040
SP-E	4	2.8	2.7	2.9	988	796	1154	1281	1112	1545

[1]Net acidity = acidity - alkalinity. Negative number indicates net alkalinity.
[2]Q1 and Q3, upper and lower quartilies determined by sorting.
[3]Less than symbol, "<" indicate that some lab values reported as "<40 mg/l" SO_4

Mine site A was activated in early 1985 and was nearing completion at the time of this writing. It occurs in an area of paleoenvironmental transition. The mine site encompasses both the coarser clastic sediments associated with the distributary channel system located in the west and the lower-energy overbank sediments, including limestones to the east. The effects of this transition are reflected in the overburden analyses and in the water quality associated with this site. Three alkaline zones were encountered at 2-10 ft, 20-25 ft, and 50-65 ft above the Upper Kittanning coal. This operation had a maximum overburden height of 85-90 ft. These zones occur as lenticular bodies that are very limited in their lateral extent. The lowest alkaline zone was an 8 ft thick lenticular parting at the top of the Upper Kittanning coal occupying an area of only about 20,000 ft^2. Some test holes starting 70 ft above the Upper Kittanning coal had little or no alkaline material present. Analysis of pit water samples have been consistently alkaline, although sulfate showed a general increase through time indicating the presence of both alkaline and acid-producing rocks. A down gradient monitoring well below the earliest backfilled area has begun to show a rise in sulfate and metals (fig. 14). The precise cause of this will require further investigation, however, some possible explanations include an insufficient amount of alkaline material present to inhibit pyrite oxidation or more acid-producing material present than anticipated. Further monitoring will be necessary to determine whether the increases in concentration are a persisting trend or a short term fluctuation.

Mining at site B was initiated in July 1983 and was completed by October 1984. The geology at mine site B is similar to mine site A. The depositional environment of the overburden rocks in the western most part of the site was the same distributary channel system found in site A. Overburden in this area consisted primarily of sandstone for a distance of 50 ft above the Upper Kittanning coal. Eastward the sandstone thinned abruptly and silts, clays and calcareous sediments were deposited in a low energy overbank environment. Two main alkaline bearing zones were found 15-20 ft and 50-60 ft above the Upper Kittanning Coal seam which was mined to a maximum highwall height of 70 ft. The two alkaline zones were found to be persistent throughout the site except in the extreme western edge. The pit water contained low concentrations of sulfate and metals and ranged from weakly acidic to weakly alkaline. Sample SP-B (table 2) from a crop spring is weakly acidic with low concentrations of sulfate and metals. The pit water at mine site B and the crop spring sample SP-B show virtually no impact from mining. Normally postmining water quality will show an increase in dissolved solids. The water quality in the deeper portions of the mine site where the rock/water contact time is greatest may not be reflected at sample point SP-B. It may be that SP-B only reflects shallow flow from the periphery of the mine site.

Mine site C was first started in January 1985 and is active at the time of this writing. Mine Site C is located almost entirely in a low energy depositional environment marked by extensive deposition of limestone and calcareous strata. As in site A three alkaline bearing zones were present at 5-10 ft, 20-25 ft and 50-60 ft above the Upper Kittanning coal seam, and the site also had a maximum overburden of 85 to 90 ft. Unlike site A however, the upper two limestone zones were found to be laterally persistent over the entire site. Also, unlike site A or B, the Lower Freeport coal was of sufficient thickness to be a minable seam. The pit water was highly alkaline with low sulfate and metals concentrations due to the abundance of alkaline rock strata present. A low flow seep, SP-C (table 2), developed below a backfilled portion of the site, is characterized as mildly alkaline, low sulfate, with metals concentration slightly above background. Because this site is still active, a full evaluation of postmining water quality is not possible and will not be until the ground water regime reestablishes itself. Seep SP-C probably represents relatively shallow flow of short retention time. Of the sites discussed this mine will encounter the largest quantity of alkaline-bearing strata due to the persistence of the calcareous zones and the large area above 40 ft of cover. It is anticipated that the alkaline material will be sufficient to prevent postmining water quality problems.

Mine site D was activated in late 1979, with mining on the decline by late

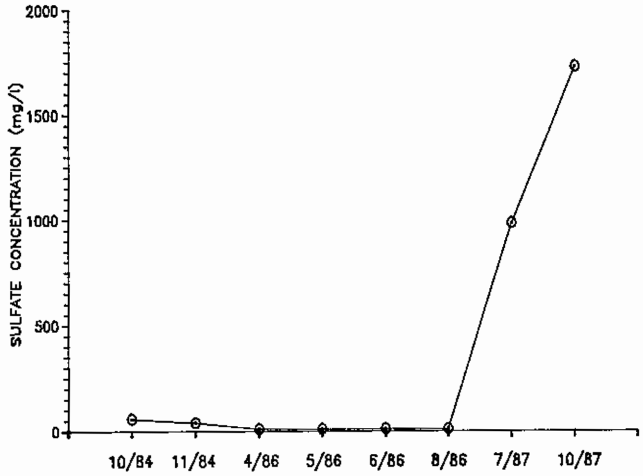

Figure 14.--Graph of Mine Site A monitoring well sulfate concentrations through time.

1981. The site has now been abandoned and has been left unreclaimed. Mine site D is located in a high energy depositional environment. This is suggested by the presence of thick coarse grained sandstone overlying the coal, a lack of calcareous strata and numerous claystone partings and boney layers in the coal. No alkaline bearing rocks were found in the overburden which reached a maximum height above the Upper Kittanning coal of 40 to 45 ft. In this site the Upper Kittanning coal uncharacteristically contains numerous carbonaceous, pyritic claystone partings sometimes as great as 2 ft in thickness. The Lower Freeport coal was generally thin to absent over the entire site except for a several acre area where it reached a minable thickness. Pit waters during mining were highly acidic with high sulfate and metals concentrations (table 1). Seeps which developed along the toe of spoil are of even poorer water quality. This quality of water is attributable to the lack of calcareous material and the indiscriminate spoiling of substantial quantities of carbonaceous, pyritic claystone partings.

Mine site E was actively mined from 1979 to 1981, when it was abandoned; it remains unreclaimed. The overburden rocks of mine site E were deposited in the north-south trending distributary channel system seen also on the western edges of mine sites A and B. Thick massive sandstones deposited in the main channel and steeply dipping interbedded siltstones and sandstones associated with point bars are the predominant rock types found over much of the site. These high energy environment deposits persist throughout the overburden as high as 85 ft above the Upper Kittanning coal. No alkaline-bearing zones were found in the Upper Kittanning overburden. As in Site D the Lower Freeport coal was generally thin or absent, except in a very small area where it became thick enough to be minable. Pit water was always of poor quality with low pH and high acidity and sulfate (table 1). Toe of spoil seeps display similar but somewhat poorer water quality characteristics (sample SP-E, table 2). In addition a pre-existing Upper Kittanning country bank deep mine 500 ft south of SP-E also showed a deterioration in water quality during active mining (Stump and Mastrilli, 1985) and continues to be degraded.

SUMMARY AND CONCLUSIONS

Based on the foregoing study of the Stony Fork watershed, the following conclusions can be made:

1) The distribution of alkaline material is the primary control on mine drainage quality. Areas lacking alkaline strata produce acid mine drainage; areas with significant alkaline strata produce alkaline water.

2) Areas where the Upper Kittanning overburden is less than 40 ft thick are devoid of alkaline material due to weathering of the alkaline zone that occurs approximately 20 feet above the coal. High sulfur content, however, occurs within strata as shallow as 10 to 15 ft from the surface. Therefore,a zone from the cropline to a 40 ft overburden thickness line lacks alkaline strata, but sulfur bearing strata still persist within this zone. Consequently, mines developed in overburden of 40 ft or less will most likely produce acid mine drainage.

3) The Upper Kittanning and Lower Freeport coals and overburden were deposited in an upper delta plain interdistributary environment. This environment is marked by narrow stream channel systems and freshwater lakes and ponds. Mine sites developed in or adjacent to the high energy paleostream channels lack calcareous materials. Coals in these areas often contain claystone partings and boney layers. Mine sites located in low energy areas away from the channels are marked by extensive calcareous deposits. Because of this variability an upper delta plain environment does not necessarily ensure good quality water.

4) Mines developed in areas of high energy depositional environments are acid mine drainage producing whereas mines developed in areas of low energy depositional environments are alkaline producing. The exception to this would be mines of low cover in low energy depositional environments that

would be acid producing due to weathering of calcium carbonate.

5) In areas of significant paleo-environmental variability, adjacent mining cannot be relied upon as a mine drainage quality predictor. Site-specific overburden analyses are important for delineating the distribution of alkaline and acidic materials.

6) Pit water quality in a broad sense appears to be a fairly good indicator of postmining water quality, although pit water quality is generally lower in metals and sulfate concentrations.

7) Mining plans should be designed such that sufficient alkaline material will be encountered. In the Stony Fork study area thickest Upper Kittanning coal development tends to coincide with areas which have the thickest sandstone overburden and which lack alkaline material. However, the coal in these areas tends to be underlain by thick limestone. A possible mining plan in these cases would involve deepening the pit in order to incorporate the underlying limestone into the spoil. In other instances when alkaline material does occur in the overburden, but only under high cover, the cuts could be run perpendicular to contour in order to blend the alkaline material evenly throughout the backfill.

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PHOSPHATIC CLAY SLURRIES FOR REDUCING ACID MINE DRAINAGE FROM RECLAIMED MINE SITES

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Abstract.-- Research at West Virginia University is being conducted on developing a phosphatic clay slurry seal that will prevent or reduce acid mine drainage produced from reclaimed sites. The spoil material that is used to reclaim sites in West Virginia consists primarily of shale and sandstone. When exposed to oxygen and water the spoil produces acid mine drainage. By developing an effective phosphatic clay slurry seal, it will be possible to hydrologically isolate the acid producing materials. An added benefit of this application is that phosphatic clay, which is a waste product of the production of fertilizer, will be utilized, thereby reducing the need for storage of these clay wastes. An effective way of hydrologically isolating the acid producting material is to reclaim sites using a layered system consisting of spoil material, overlain with a phosphatic clay slurry which is in turn overlain by cover soil. Current research is being conducted to define an optimum system that will produce the lowest permeability and reduce the acidity of any effluent generated in the acid materials. To date, laboratory permeability test results indicate that the compactive effort is the dominant variable in determining the permeability of the spoil-slurry system. Low water content slurries (150% to 250%) should be applied to uncompacted spoils, and high water content (250% to 350%) slurries should be applied to compacted spoils. The thickness of the slurry does not appear to significantly alter the permeability of the spoil-slurry system. The addition of the slurry has resulted in a 40 to 80 percent decrease in the permeability of the spoil material. The addition of slurry also dramatically decreases the concentrations of iron, manganeese, magnesium, aluminum, and sulfates in the effluent. Slight increases in the pH of the effluent were also demonstrated. Additional testing is underway to establish the optimal conditions for obtaining minimum permeabilities.

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