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Influence of Overlying Strata on Methane Emissions in a Northern West Virginia Coal Mine

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UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter	mi	mile
cm^3/g	cubic centimeter per gram	m^3/d	cubic meter per day
ft^3/d	cubic foot per day	$MMft^3/d$	million cubic feet per day
ft^3/t	cubic foot per ton	ft	foot
h	hour	in	inch
m	meter	′	minute of arc

INFLUENCE OF OVERLYING STRATA ON METHANE EMISSIONS IN A NORTHERN WEST VIRGINIA COAL MINE

By J. P. Ulery [1] and G. M. Molinda [1]

ABSTRACT

Since 1970, abnormally high methane emissions have been observed in eastern sections of the Federal No. 2 Mine operating in the Pittsburgh Coalbed in northern West Virginia. The nature and volume of these emissions indicate a source other than the coalbed. An investigation was undertaken to delineate probable methane sources. Gas well information and stratigraphic correlation of corehole data indicates that a sandstone directly above the main coalbed is an additional source of methane emissions. The sandstone body appears to be an ancient stream channel, infilled with fine-grained sand and organic matter. Coalification of the organic matter produced methane as a byproduct. Additional methane presumably migrated into the sandstone unit from the subjacent coalbeds. The methane became trapped in the porous clastic unit by the surrounding impermeable strata. Mine development near this unit creates a significant pressure gradient, triggering abnormal methane emissions into the mine along naturally occurring fractures. Predevelopment methane drainage of the sandstone could be accomplished by completing vertical boreholes along its trend.

[1] Geologist.
Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.

INTRODUCTION

The Federal No. 2 Mine straddles the Wadestown and Blacksville 7.5′ quadrangles and is located near the town of Wadestown in western Monongalia County, WV (fig. 1). Monongalia County has a long history of fuels production beginning with its first recorded coal production in 1836. Oil production in the western part of the county began about 1892. Drilling specifically for oil, however, has virtually ceased since 1910 (12).[2] Numerous gas wells were drilled during and shortly after World War I, and the area remained fairly active until the mid-1930's. Since 1940, drilling has been sporadic with little success (12).

Coal is by far the most important fuel commodity of the county. Western Monongalia County has proven minable reserves of the Washington, Waynesburg, Sewickley, and Pittsburgh Coalbeds (26). The Federal No. 2 Mine operates in the Pittsburgh Coalbed and produces about 2 million tons annually from seven working sections. The main bench of the Pittsburgh Coalbed ranges from 84 to 103 in (210 to 265 cm) in thickness over the study area. The main bench is immediately overlain by an interval of interbedded shales, clay shales, and rider coalbeds.

The Federal No. 2 Mine began production in 1967. The mining method was originally continuous; however, a number of longwall panels have been developed recently. Some original entries were driven using

[2]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

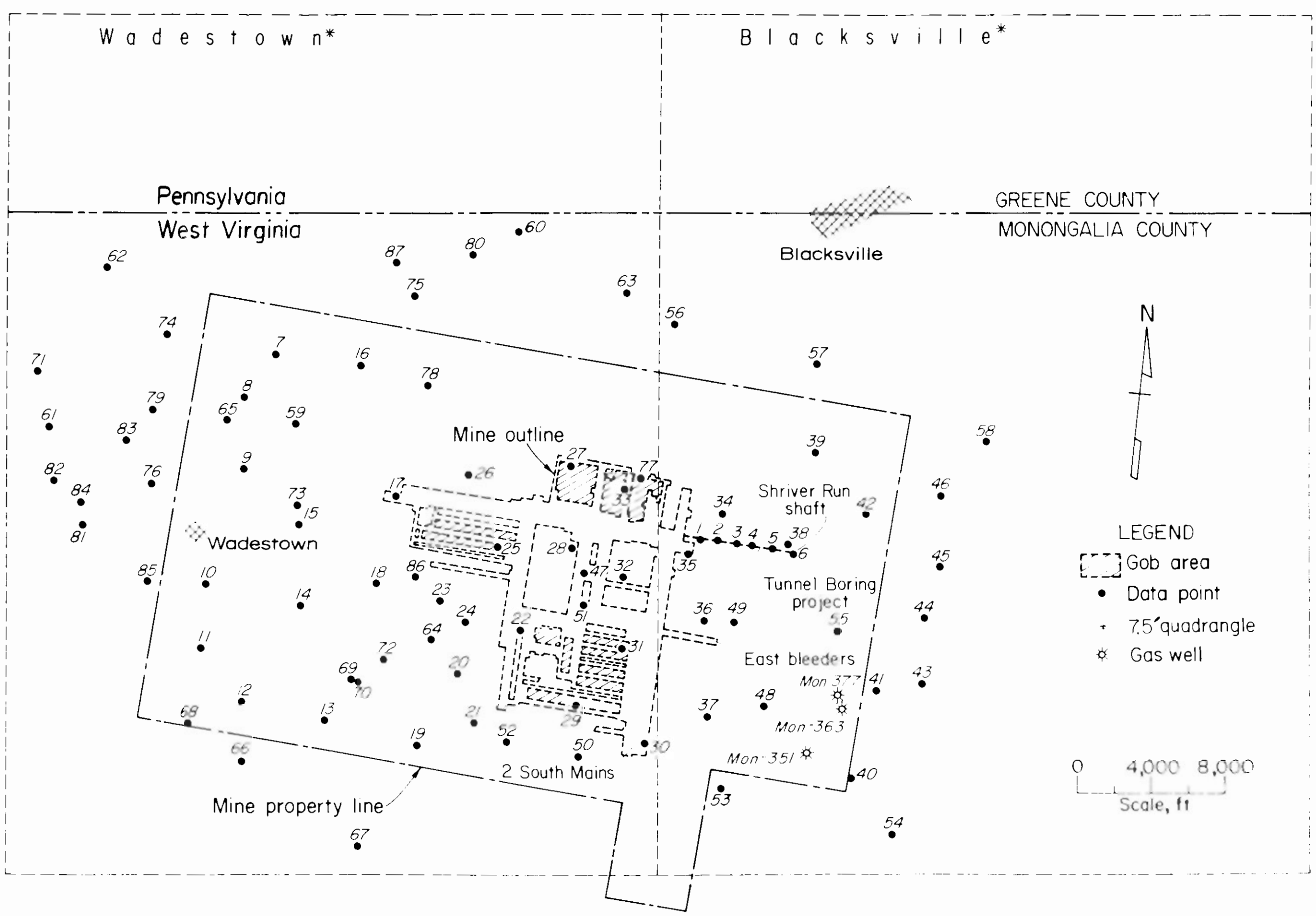

FIGURE 1. - Location of study area.

a tunnel-boring machine; now most are driven by continuous-mining machines.

The Federal No. 2 Mine has been the site of several Bureau of Mines investigations relating to methane occurrence and emissions (10-11, 35). The purpose of this investigation is to assess the geologic factors influencing abnormally high methane emissions associated with the East bleeders development, the sinking of Shriver Run shaft and a tunnel-boring project.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the cooperation of Federal No. 2 Mine personnel and Eastern Associated Coal Corp., especially Frank Peduti, electrical engineer, and Gary McHenry, division accident investigator. The authors also wish to acknowledge Albert Sainato, mining engineering technician of the Pittsburgh Research Center, for his contribution to the drilling and emission data in the section on methane occurrence and emission.

STRATIGRAPHY

The minable coalbeds of southwestern Pennsylvania and northern West Virginia belong to the Pennsylvanian System deposited approximately 280 to 310 million years ago. The Pittsburgh Coalbed is the basal unit of the Monongahela Group deposited during the late Pennsylvanian. The Monongahela Group contains the Pittsburgh, Redstone, Sewickley, and Uniontown Coalbeds and exhibits cyclical accumulations of sediments in fluvial and lacustrine environments (4, 7-8, 16, 21).

The Monongahela Group is subdivided into the Pittsburgh and Uniontown Formations (2). The Pittsburgh Formation extends from the base of the Pittsburgh Coalbed to the base of the Uniontown Coalbed and ranges from 275 to 350 ft (84 to 107 m) in thickness across the study area. The Pittsburgh Formation is further subdivided into the following five members, in ascending order: Lower, Redstone, Fishpot, Sewickley, and Upper. This investigation is primarily concerned with the lower three members (fig. 2).

In the study area, the Lower Member is 25 to 45 ft (8 to 14 m) thick, and includes the interval from the base of the Pittsburgh Coalbed to the base of the Redstone Coalbed. Above the Pittsburgh Coalbed lies the rider coalbed interval, a 1.5- to 8-ft (5 to 25 m) sequence of soft, gray, clay shales and brittle, dark, carbonaceous shales interbedded with up to five coalbeds. The rider coalbeds vary in thickness from 2 to 29 in (5 to 75 cm); the thicker coalbeds tending to be bony and impure. Overlying the rider coalbed interval and extending upward to the Redstone Coalbed is a medium to dark gray limy shale that grades laterally and vertically into gray, shaly limestone and fine-grained nonmarine limestone. In portions of the study area, the limestone-shale facies gives way to fine-grained sandstone and sandy shale.

The Redstone Member ranges from 25 to 35 ft (8 to 11 m) in thickness and extends from the base of the Redstone Coalbed horizon to the base of the Fishpot Coalbed horizon. The Redstone Coalbed ranges from 0 to 22 in (0 to 56 cm) thick. It is often overlain by a soft clay shale 1 to 5 ft (0.3 to 1.5 m) thick and occasionally by a dark siltstone of similar thickness. The remaining thickness is composed primarily of hard, gray, fine-grained, nonmarine limestone, grading laterally into gray shaly limestone and calcareous shale.

The Fishpot Member is 20 to 30 ft thick and extends to the base of the Sewickley Coalbed. The Fishpot Coalbed ranges from 0 to 12 in (0 to 30 cm) in thickness and is fairly persistent across the study area. Overlying the Fishpot Coalbed horizon is usually 1 to 5 ft (0.3 to 1.5 m)

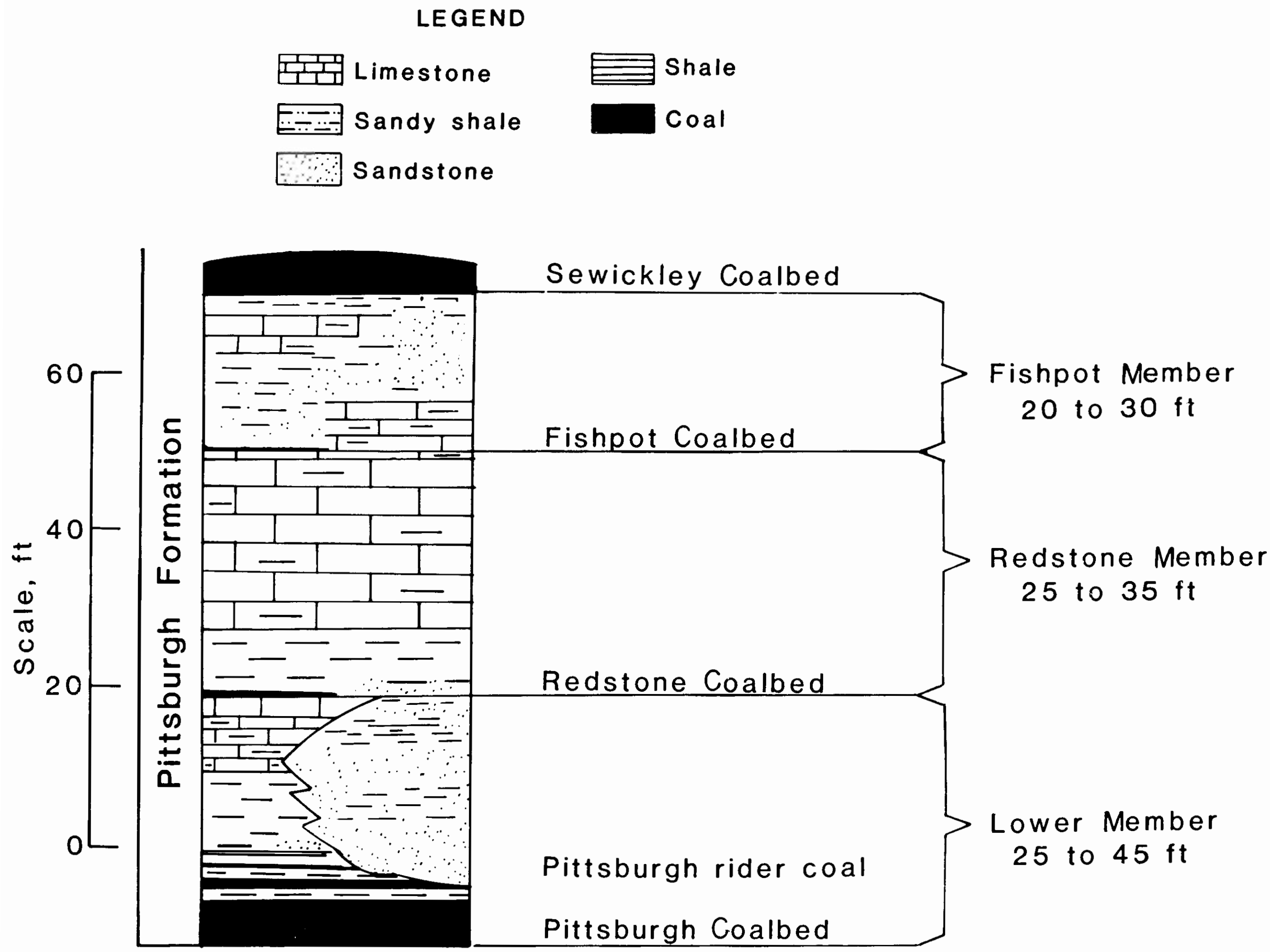

FIGURE 2. - Generalized stratigraphic section of Pittsburgh Formation in study area.

of gray shale or clay shale. Above this shale, in much of the study area, is a coarser clastic sequence of gray sandy shale and minor fine-grained sandstone 3 to 25 ft (1.0 to 8.0 m) thick. Above the unit is 1 to 4 ft (0.3 to 1.0 m) of clay shale or dark, carbonaceous shale that directly underlies the Sewickley Coalbed. Where the sandy shale-sandstone sequence is absent, gray fine-grained limestone or limy shale is present.

Above the Fishpot Member is the Sewickley Coalbed, persistent throughout the study area. The Sewickley Coalbed ranges from 3 to 5 ft (1.0 to 1.5 m) in thickness and is usually overlain by a massive sandstone up to 50 ft (15 m) thick.

STRUCTURE

The Federal No. 2 Mine property lies in the Pittsburgh Plateau section of the Appalachian Plateau physiographic province. The Pittsburgh Plateau section is characterized by broad open folds generally trending northeast-southwest with little or no faulting present.

Just northeast of the mine property are the southern terminations of two major structural features, the Belle Vernon anticline and the Whitely syncline (30-31). The mine property itself lies approximately midway between the axes of the Mooresville anticline to the east and the Waynesburg syncline to the west (fig. 3). The local westward dip of the coalbed between these structures is interrupted in the central portion of the property by a minor upwarp and depression, the origin of which is problematic.

Abundant coal cleat, rock joint, and photolinear data for the area has been compiled by previous Bureau workers (1, 6, 23) and will only be briefly summarized here. Main coal cleats and rock joints presumably formed as a result of the build up of tectonic stresses prior to folding (27). Interpretation of photolinear trends is more problematic; however, they are assumed to be fracturelike features also related to regional tectonic stresses (1, 6).

Coal cleat data from the Federal No. 2 Mine shows an average face cleat orientation of N 77° W and an average butt cleat orientation of N 17° E (6, 24). Joint data from surface outcrops in the study area shows a number of directional trends. A total of 260 joint orientations and 816 photolinear readings were plotted on rose diagrams and analyzed for directional trends (6). The dominant joint and photolinear trends, however, showed a good correlation to coal cleat trends. The results of the investigations demonstrated a fundamental relationship between the orientations of the coal cleat, bedrock joints and fractures, and regional structural axes (1, 6).

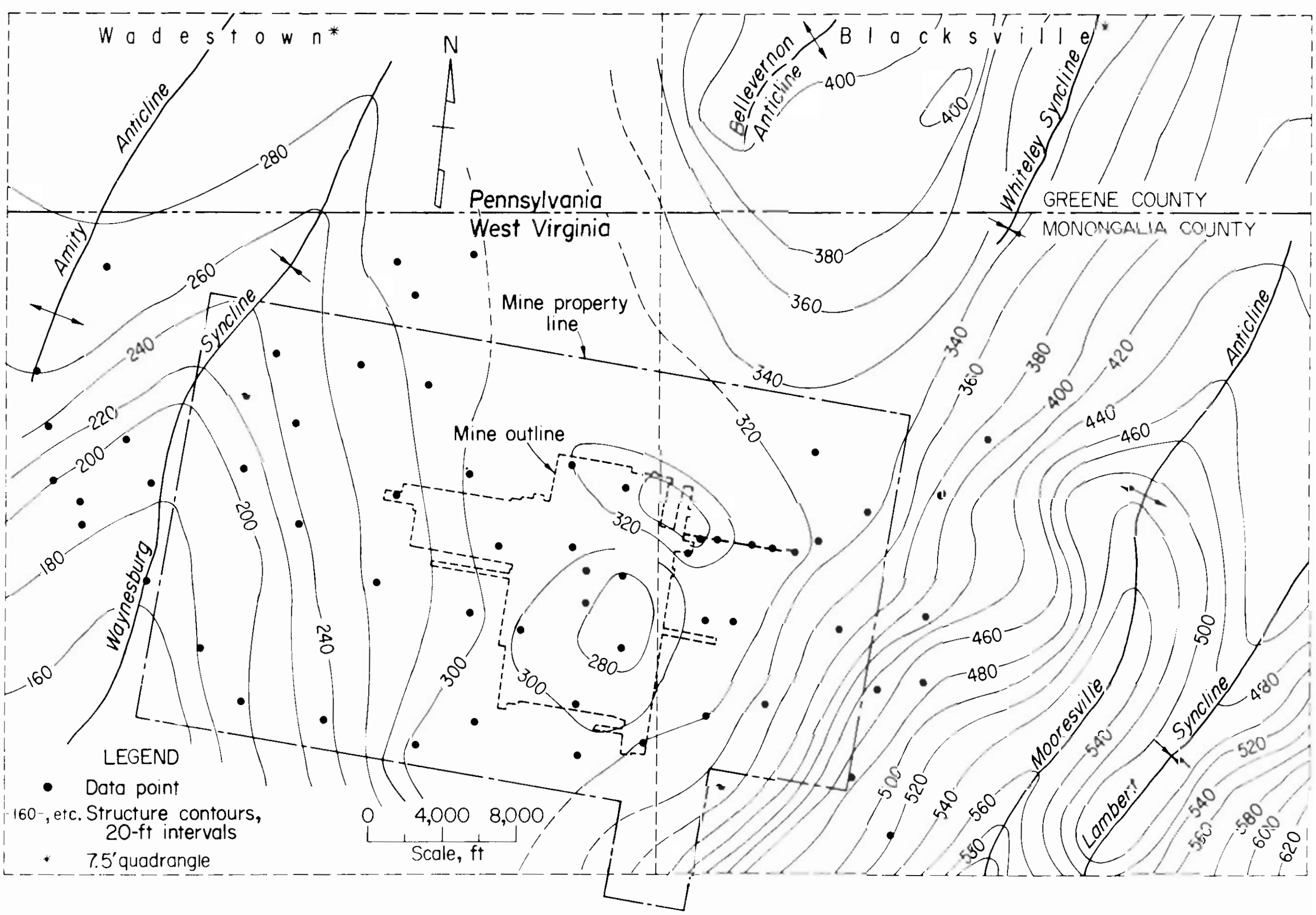

FIGURE 3. - Structural contour map drawn on base Pittsburgh Coalbed.

METHANE OCCURRENCE AND EMISSION

Methane occurrence in the coalbeds of the Pittsburgh Formation in southwestern Pennsylvania and northern West Virginia has been documented through Bureau of Mines direct-method testing. Gas content of these coalbeds is significant, with the Pittsburgh Coalbed having values ranging from 89.6 to 265.6 ft^3/t or 2.8 to 8.3 cm^3/g (5).

As previously stated, the Federal No. 2 Mine has been the site of a number of Bureau of Mines studies dealing with the emission, drainage, and utilization of coalbed methane. One study of particular interest demonstrated that methane emissions into mine workings are influenced by the presence of nearby oil and gas wells (35). This influence was also noted in later methane drainage work (10-11).

This study was undertaken as a consequence of abnormally high methane emissions observed on the eastern side of the mine. Abnormal methane emissions were first encountered during driving of the East bleeders section (fig. 1) in 1970-71. Before full development, the section was sealed off and a vertical drainage hole was drilled from the surface. Accurate records of the ventilated gas were not kept; however, emissions have been sufficient to prevent mine personnel from reopening the section.

In 1978, Shriver Run shaft was sunk along Shriver Run just west of Daybrook, WV. The shaft was located approximately 6,000 ft (1,830 m) from the mine workings and was to be connected by a tunnel bored from 1 North Mains (fig. 1). Methane emission problems first occurred while the shaft was being sunk. When the shaft bottom was approximately 50 ft (15 m) above the Pittsburgh Coalbed, abnormal methane flows were encountered. To alleviate this problem, about 14 holes were drilled radially downward and outward from the shaft bottom to within 5 ft (1.5 m) of the Pittsburgh Coalbed. Gas from these holes was piped to an 8-in (20-cm) vertical pipe and vented at the surface. Approximately 2 years after the shaft was sunk, the vertical drainage pipe had a gas flow of 370,000 ft^3/d and had produced an estimated 270 $MMft^3/d$ of gas (33). Since then these holes have produced gas continuously, although at present the flow rate is negligible.

Further methane emission problems developed during drivage of the 6,000-ft (1,830-m) tunnel to intercept the shaft. When the tunnel boring machine penetrated a clastic dike[3] about 125 ft (38 m) from the shaft bottom, methane emission problems developed that could not be controlled by ventilation alone. In an attempt to decrease emissions into the tunnel, nine horizontal degasification holes were drilled from the tunnel and shaft into the main coalbed or one of the rider coalbeds. The final three holes were drilled at a low angle upward through the rider coalbeds, into the clay vein and associated fracture system. These holes showed abnormally high methane flows (220,000 ft^3/d or 67,056 m^3/d) (33) and significantly lowered emissions, allowing tunnel drivage to continue to Shriver Run shaft.

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[3]The term "clastic dike" is the proper scientific terminology for approximately vertical, tabular, sediment-infilled discontinuities in coalbeds; however, "clay vein" is so firmly established in coal mine terminology that it will be used instead of clastic dike throughout this report. Clay veins usually extend into the mine roof and are commonly associated with warped, fractured and slickensided roof strata (9, 14).

DISCUSSION

Commercial-quality methane gas has been produced from the Pittsburgh Coalbed in the southwestern (11) and western (10) portions of Federal No. 2 Mine property. The eastern portion of the property, however, has experienced abnormally high methane emissions associated with driving of the East bleeders and later with the sinking of Shriver Run shaft and the tunnel-boring project.

These abnormal emissions appear to be associated with a minor sandstone body delineated by isopaching corehole data. Figure 4 is an isopach of the thickness percentage of sandstone and sandy shale in the Lower Member of the Pittsburgh Formation. The map shows a north-south trending sandstone facies developed near the eastern edge of the property, as well as a lobe extending westward across active workings.

Figure 5 is an isopach of the rider coalbed interval above the Pittsburgh Coalbed. The map shows a north-south thinning trend congruent with the north-south sandstone trend. The thinning then is probably due to erosion of the upper rider coalbeds by the sandstone unit, presumably a minor paleochannel. The east-west sandy trend, however, does not appear to affect the rider coalbed interval. Examination of core logs over the property shows that the sandstone unit changes from an approximately equal mixture of sandstone and sandy shale in the north-south direction to entirely sandy shale along the western lobe. The western lobe possibly represents deposition

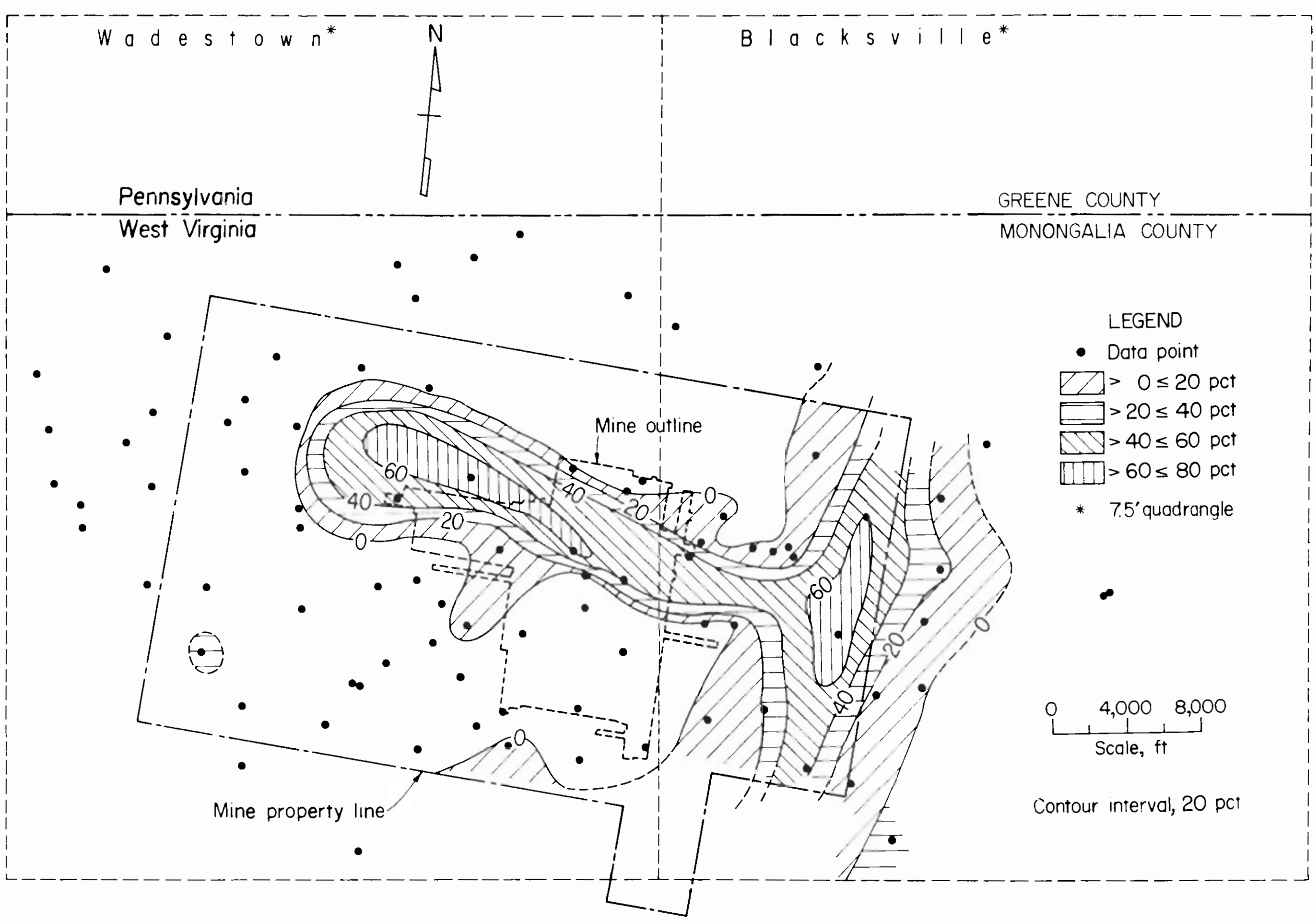

FIGURE 4. - Percentage of sandstone in the Lower Member of the Pittsburgh Formation.

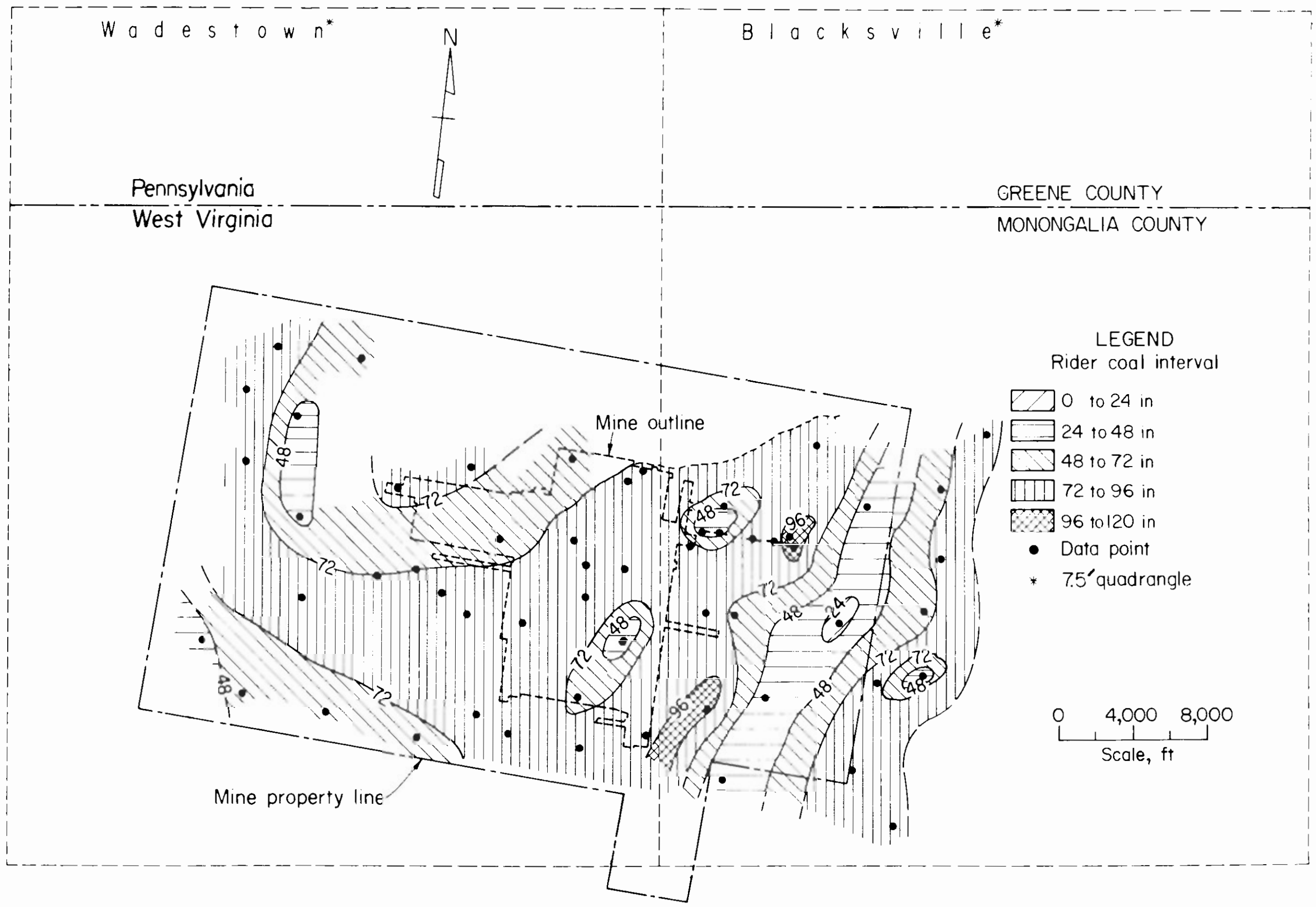

FIGURE 5. - Isopach of rider coal interval above the Pittsburgh Coalbed.

in a lower energy environment; therefore, the rider coalbeds were not eroded. The location of this sandstone unit corresponds with Pittsburgh sandstone mapped on a more regional scale (16, 32).

The presence of the sandstone was not detected in underground reconnaissance as present workings are still 1,000 to 2,000 ft (305 to 610 m) from the approximate edge of this unit. Some indirect evidence indicating the presence of the sandstone channel was observed, however. First, clay vein occurrence is more frequent in the southeastern portion of the mine. A number of workers have noted increased clay vein and fracture frequency associated with the margins of sandstone channels (18, 20, 22, 24, 34). Clay veins at Federal No. 2 Mine are very infrequent in western portions of the mine workings; they are most frequent in the southeastern corner. The southeastern corner (2 South Mains area, figure 1) is the area of present workings closest to the mapped channel. A clay vein was also encountered extremely close to the sandstone unit at the site of the methane emission problem during the tunnel-boring project.

Observed clay veins were generally U- to V-shaped and cut out 2 to 6 ft (0.6 to 1.8 m) of coal laterally and 1 to 4 ft (0.3 to 1.0 m) of coal vertically. Most of the clay veins observed had a thin stringer of clay or a fracture extending nearly to the floor. Roof expressions of the clay veins were apparent as 3- to 5-ft (1.0- to 1.5-m) wide zones of irregularly fractured top containing subrounded limestone blocks that form hummocky, "pillowlike" structures. In cross section, the clay veins were composed of numerous large, subrounded to subangular blocks of light to medium gray, fine-grained limestone in a matrix of indurated, brittle, medium to dark gray shale. Most clay veins showed minor, normal fault displacement and a downwarping of upper coal layers. A typical clay vein is shown in figure 6.

Besides clay veins, poor roof conditions in the area of 2 South Mains also suggest the presence of a nearby sand channel. Although no major roof falls were observed, mine personnel indicated that roof conditions were generally poorer here than in other areas of the mine. Areal sloughing of roof rock was observed underground, generally trending linearly along north-south-oriented entries. Minor dome-shaped falls were observed at several intersections. The deterioration of roof conditions near sand channels has been widely documented (17-19, 22, 24-25).

Only indirect evidence is available relating the sandstone channel to abnormal methane emissions encountered in the eastern portions of the mine property. It seems unlikely that the methane source could be the main coalbed for two reasons. First, no methane problems were encountered cutting the main bench during the tunnel-boring project. Methane problems did occur, however, 50 ft (15 m) above the coalbed during sinking of Shriver Run shaft, and in the tunnel when the boring machine intercepted roof strata while cutting a clay vein. Secondly, after tunnel drivage ceased due to abnormally high methane emissions, degasification holes drilled into the main bench showed negligible gas flows and had little effect on lowering emissions at the tunnel face (33).

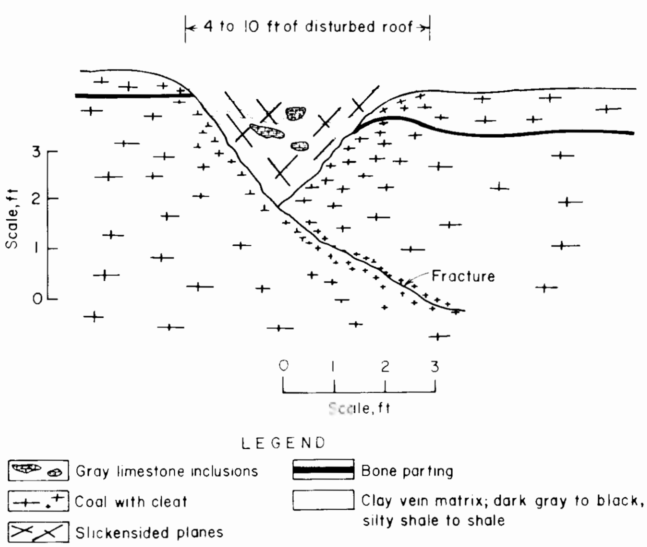

FIGURE 6. - Cross-sectional view of typical clay vein.

Horizontal holes drilled into the rider coalbeds also had negligible flows and did little to lower emissions after tunnel drivage had ceased. However, extremely high flows (>80,000 ft^3/d or 24,384 m^3/d) were recorded for three short, low-angle holes drilled upward through the rider coalbed sequence into the clay vein and associated fracture system (33). Gas flows from these holes lowered emissions enough at the tunnel face to allow drivage to continue. Based on past experience it seems unlikely that the rider coalbed sequence alone could be responsible for the volume of gas emitted (33). One must assume then that the gas migrated along the clay vein and associated fracture system from another source.

Two possible sources exist for the abnormal methane emissions: a shallow, conventional gas reservior,[4] or migration of gas from existing oil and gas wells. The positive effect of oil and gas wells on methane emissions into mine workings was documented by the Bureau more than 10 years ago (35). The magnitude of the methane emission problem in the eastern area was apparent even then. In that Bureau report, the East bleeders section, driven parallel to face cleat, showed the highest methane concentration and emission rate of any individual section in the mine (35, figure 2). Other Bureau of Mines research has shown that horizontal degasification holes and mine entries oriented parallel to the face cleat show minimum gas flows, while those oriented perpendicular to the face cleat show maximum flows (23). The East bleeders section is an anomaly to this rule because it shows significantly higher methane

[4]The gas is trapped stratigraphically and/or structurally in porous sandstones or limestones.

emissions than do sections driven perpendicular to the main cleat.

The area selected by Zabetakis et al (35) to show the relationship of oil and gas wells to methane emissions is the northeastern corner of the mine, the area where the tunnel-boring project began. Careful examination of their data shows that although oil and gas wells appear to influence methane emission in nearby return airways, communication between the well and mine workings in some cases must not occur along the face cleat. The data presented (35) suggest that communication would likely occur along a fracture system oriented at a large angle (greater than 60°) to the face cleat. This fracture system could be related to clay vein occurrence. Limited underground mapping confirms a distinct clay vein trend at a large angle to the face cleat.

Consequently, if the tunnel (also driven parallel to the face cleat) were to develop methane problems associated with leakage from oil and gas wells, it would seem likely that communication with the tunnel would occur along the previously mentioned clay vein and fracture systems. It also would likely have occurred within the first 2,000 ft (610 m) of drivage where the tunnel passed within 200 ft (61 m) of three wells, and within 500 ft (152 m) of another (12). However, the methane problem occurred more than 5,000 ft (1,525 m) from the mine workings, at a point where no wells are known within 1,500-ft (458-m) radius. Communication with the tunnel definitely occurs along a clay vein and associated fracture system (33), and the gas source was probably the nearby sandstone channel (figs. 4-5). Figure 7 shows the sandstone unit, its relation to surrounding

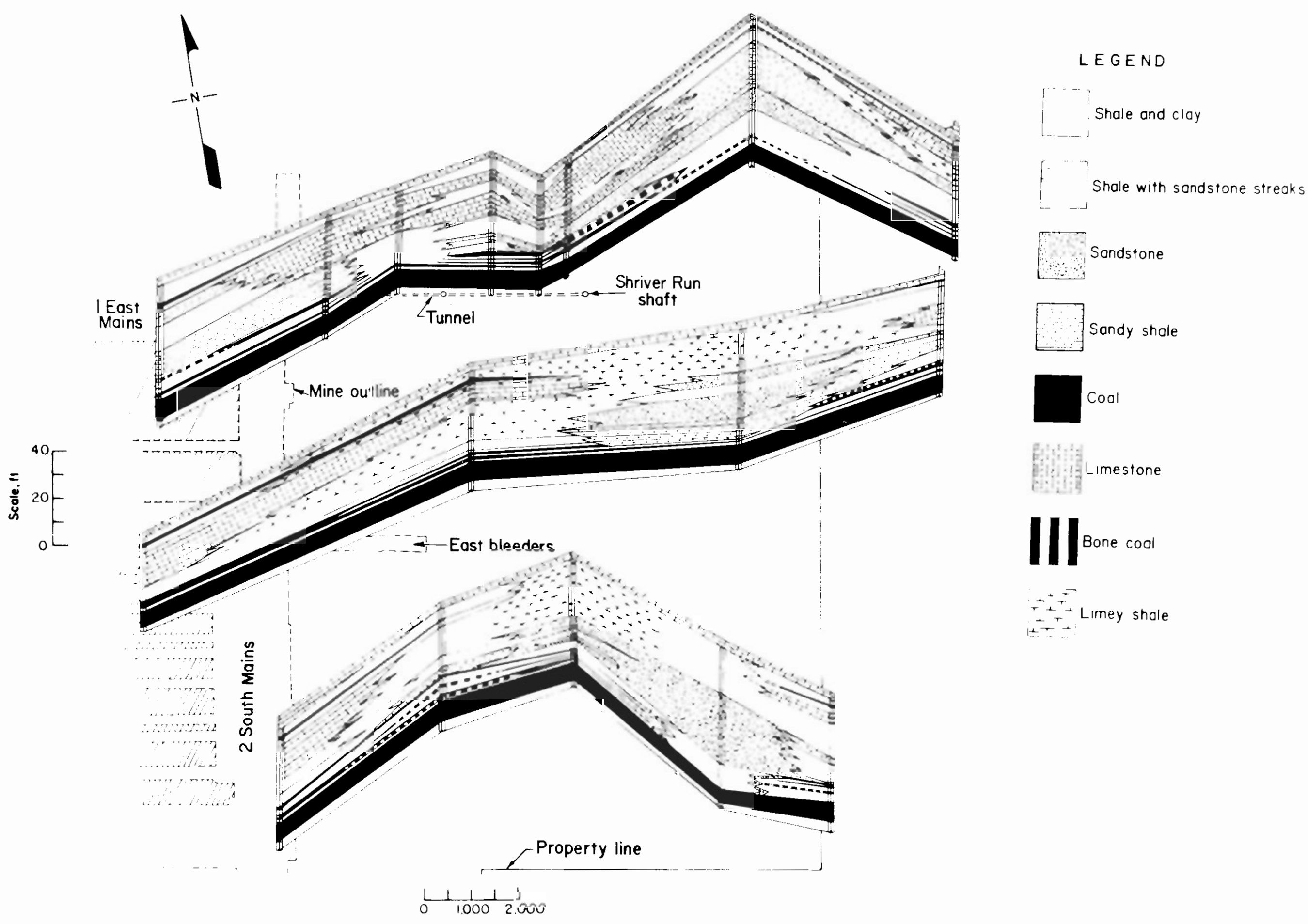

FIGURE 7. - Panel diagram of eastern portion of study area.

strata, and its location with respect to mine workings.

Gas production from shallow horizons in the Pennsylvanian coal-bearing strata of northern West Virginia is not unknown. A 1937 report (28) characterizing the physical and chemical properties of West Virginia natural gases included several samples of coalbed-associated gas. Most of these samples were taken from wells producing in the Pittsburgh Coalbed horizon along a northeast-southwest trending line in eastern Wetzel County, about 15 mi west of the present study area. In a report on oil and gas in Monongalia County (12), the author states that "...a little gas has probably been produced from the Pittsburgh coal in the western part of Monongalia County." He also notes that other Pennsylvanian sands in this area "...produced gas from widely scattered rather small wells and groups of wells... since about 1925, however, many wells have been drilled for gas production from these sands, with a moderate degree of success." Several other areas showing production from Pennsylvanian strata have also been noted (3).

Further evidence for a conventional shallow gas reservoir was obtained by examining well records at the West Virginia Geological and Economic Survey. Three wells targeted for deeper horizons (fig. 1) located along the north-south sandstone trend, produced significant initial gas flows from the Pittsburgh Coalbed horizon. Well Mon-351 completed to about 75 ft (22.9 m) below the Pittsburgh Coalbed showed an initial open-flow potential of 21,000 ft^3/d (6,400 m^3/d), which was sustained for 8 h before being plugged. The specific production horizon was not identified on the well record; however, 31 ft (9.5 m) of sandstone was logged above the Pittsburgh Coalbed. Well Mon-377 was completed to about 50 ft (15 m) below the Pittsburgh Coalbed. Again, the specific producing horizon was not identified; but an initial open-flow potential of 20,000 ft^3/d (6,096 m^3/d) was sustained for 10 h before cementing. Well Mon-363 was drilled to about 45 ft (14 m) below the Pittsburgh Coalbed. The driller's log indicates a gas "show" from a "soft shale" immediately above the coalbed. Initial open-flow potential was noted at 17,000 ft^3/d (5,182 m^3/d); final open flow before cementing was 12,000 ft^3/d (3,658 m^3/d). The length of time the well was open was not noted.

CONCLUSIONS

Evidence indicates that abnormal methane flows associated with the tunnel-boring project, sinking Shriver Run shaft and East bleeders development are probably due to the presence of a shallow gas reservoir trending north-south along the eastern border of the Federal No. 2 Mine property. Significant gas production from the more shallow coal-bearing strata of northern West Virginia has been documented (3, 12-13, 15, 28).

The reservoir rock is a sandstone apparently grading upward and laterally into a sandy shale. Isopaching of corehole data shows that the configuration of this unit is that of a distributary channel with a finer grained, westward-extending lobe, possibly representing a crevasse splay (29). The channel was probably partially infilled with fine sand and organic debris as it eroded into the rider coalbed sequence. Later, finer sediments, along with additional organic matter, may have been washed in during flooding of the Redstone peat (coal) swamp.

Deep burial and tectonic activity followed, transforming the organic matter accumulated in peat swamps into coal. Coalification of the organic matter in the sandstone produced methane as a by-product. Gas formed from organic matter in the westward-oriented lobe migrated up dip into the main channel system. Some methane formed during coalification of the subjacent coalbeds and may also have migrated into the sandstone. The gas was stratigraphically trapped in the sandstone by the impermeable limy shales and fine-grained limestones surrounding it.

Clay veins and fractured, slickensided roof have been observed in mine workings nearest the channel. Presumably, these formed as a result of differential compaction and stratal readjustments due to overburden and tectonic stresses in the less competent shales adjacent to the sandstone unit (17-19, 22). Mining near these features redistributes stresses, often causing the fractures to open, allowing gas migration into mine workings as the channel is approached.

The most feasible premining methane drainage system would utilize vertical boreholes and/or shaft degasification techniques (10-11). Previous Bureau of Mines research has shown that these degasification procedures can reduce methane emissions and provide a safer work environment.

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