RI 9403

REPORT OF INVESTIGATIONS/1992

Influence of Subjacent Gob on Longwall Development Mining in the Upper Kittanning Coalbed of South-Central Pennsylvania

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UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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Library of Congress Cataloging in Publication Data:

Bauer, Eric R.

Influence of subjacent gob on longwall development mining in the Upper Kittanning Coalbed of south-central Pennsylvania / by E.R. Bauer, G.J. Chekan, and G.P. Sames.

p. cm. — (Report of investigations / U.S. Dept. of the Interior, Bureau of Mines; 9403)

Includes bibliographical references (p. 13).

Supt. of Docs. no.: I 28.22:9403.

1. Ground control (Mining)—Pennsylvania—Ebensburg Region. 2. Longwall mining—Pennsylvania—Ebensburg Region. 3. Coal mine waste—Pennsylvania—Ebensburg Region. I. Chekan, G. J. (Gregory J.) II. Sames, Gary P. III. Title. IV. Series: Report of investigations (United States. Bureau of Mines); 9403.

TN23.U43 [TN288] 622 s—dc20 [622'.334] 91-43726 CIP

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	pct	percent
gal/min	gallon per minute	st	short ton
in	inch		

INFLUENCE OF SUBJACENT GOB ON LONGWALL DEVELOPMENT MINING IN THE UPPER KITTANNING COALBED OF SOUTH-CENTRAL PENNSYLVANIA

By E. R. Bauer,[1] G. J. Chekan,[1] and G. P. Sames[2]

ABSTRACT

The U.S. Bureau of Mines is investigating strata interactions associated with mining of multiple coalbeds to provide the mining industry with improved methods of planning and developing multiple coalbeds, conserving resources, and increasing the safety of underground coal mining. This study involves analytical predictions and underground observations of longwall development ground control problems at a south-central Pennsylvania coal mine affected by subsidence induced by multiple-seam mining. As predicted, strata interactions were found in upper mine areas mined over lower mine gob. Observations revealed roof deterioration accompanied by excessive water inflows in the first 170 ft after crossing the gob line as mining entered and exited the subsided area (over the lower mine gob). In contrast, superimposed mine areas and areas mined a substantial distance out over the gob showed no signs of interaction with previous lower seam mining, again as predicted.

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INTRODUCTION

Mining of adjacent coalbeds, either simultaneously or over or under previously mined-out coalbeds, occurs frequently in the Appalachian Region of the Eastern United States. This mining of adjacent coalbeds is expected to increase dramatically in the future. In the Eastern Coal Region alone, estimates place over 70 billion st of minable reserves in multiple-seam configurations (*1*).[3] In the past, no particular attention was paid to the order in which coalbeds were mined. Seam sequencing was based on ownership, availability, and economics, with little concern for the conservation of adjacent coalbeds. The result was sterilization of some coal reserves because strata interactions left them unminable by current methods.

Multiple-seam interactions in longwall operations have been reported in various studies (*2-8*). A variety of parameters influence interactive distance, magnitude, and location. Geology was shown to be an important factor in seam interaction. The characteristics of the innerburden and overburden, including thickness, stratification, and composition, influence interaction to some extent. For instance, seam interaction has been documented where the innerburden thickness ranged from less than 110 ft to as much as 750 ft, implying that seam interaction cannot be dismissed based on a large innerburden alone (*4*). Other factors that influence interactions are the height and percentage of extraction of the lower coalbed and the time between mining of the upper and lower coalbeds (*9*). A more comprehensive discussion of the parameters influencing seam interaction can be obtained in the references listed above.

The study detailed in this report involves undermining and the resultant subsidence of an overlying coalbed. When longwall is the method of undermining, the damage to overlying coalbeds depends on their location and the height of the fracture zone. The height of the fracture zone is defined by the angle of draw and geologic environment. Previous studies estimate that the fracture zone ranges from 30 to 50 times the lower seam mining height. Coalbeds within 10 to 15 times the mining height are susceptible to severe damage (*3, 10*). Ground control problems in the overlying coalbeds are most likely to occur near the boundaries of the subsidence trough (pillar-to-gob transition line). This is where tensile and compressive stresses form because of strata flexure (fig. 1). As mining in the upper coalbed progresses through this zone, the stresses can cause ground instability (*4, 11-13*).

The economic attractiveness of longwall mining has led to a steady increase in the percentage of coal produced by this method. Accompanying this increase in productivity is the increased likelihood of encountering subjacent and superjacent workings. The U.S. Bureau of Mines is actively documenting the effects of overmining and undermining on longwall development. This research was conducted to gain insight into the effects of multiple-seam workings on longwall development, leading to improvements in longwall planning, design, and production; conservation of national resources; and improved safety of underground coal mining operations.

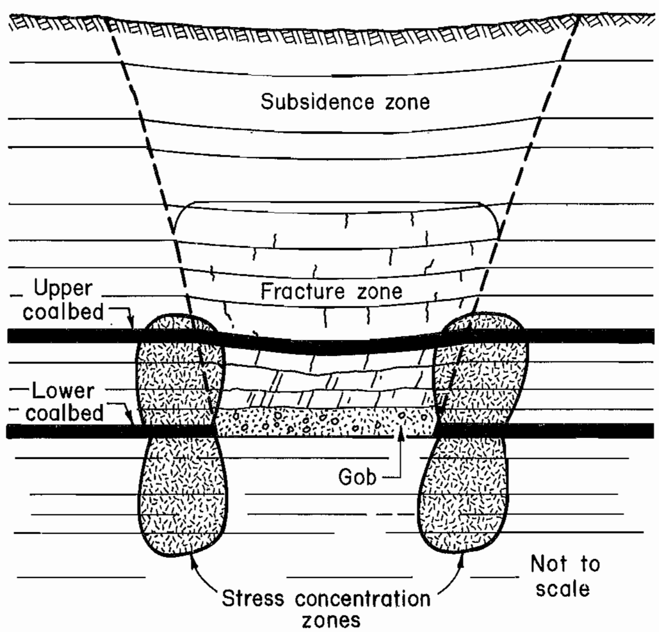

Figure 1.—Influence on upper coalbed due to undermining in lower coalbed.

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

MINE LOCATION AND GEOLOGIC SETTING

The study mine is located in south-central Pennsylvania near Ebensburg in Cambria County (fig. 2). Cambria County lies physiographically within the Allegheny Mountain section of the Appalachian Plateaus province. Local geologic structures include folds, faults, joints, and cleats in the coal. These structures appear to have a genetic relationship with the Allegheny Front (*14*). The mine workings are influenced mainly by the Ebensburg anticline and Wilmore syncline (*15*).

This mine is part of a two-mine complex (fig. 3) that includes a common manshaft, supply yard, preparation plant, bath house, and offices. The mines have a long history of both room-and-pillar and longwall mining. The lower mine is extracting the Lower Kittanning Coalbed (also known as the B seam). Mining of the B seam started in the mid-1960's, and the first longwall panel was installed in 1968. The upper mine is extracting the Upper Kittanning Coalbed (also known as the C Prime seam). Mining of the C Prime seam began in the early 1970's, and the first longwall was installed in 1975. To date, the mines have combined to extract approximately 80 longwall panels over the past 2 decades.

The main entries for both mines run along an axis approximately halfway down the eastern limb of the Ebensburg anticline and split the coalbeds into two equal sections (*15*). B seam workings are more extensive, and coal has been completely extracted by longwall mining in the areas underlying active C Prime seam workings. Present production in the upper coalbed comes from the western or raise side, while production from the lower coalbed comes from the eastern or dip side. In the study areas, the time between longwall panel extraction in the lower coalbed and panel development mining in the upper coalbed averaged 11 years. This is sufficient time for complete subsidence and gob compaction to occur. Superpositioning of main entries, gate roads, and longwall panels was practiced in most instances. Past mining of the C Prime seam over virgin B seam resulted in severe ground conditions and methane emissions. Mining of the B seam tended to provide relief from these conditions.

The Upper Kittanning Coalbed lies stratigraphically within the Pennsylvanian-age coal-bearing strata of the Allegheny Group (fig. 4). The coalbed averages 42 in thick, with extraction heights from 52 to 80 in, depending on roof conditions. Overburden at the test sites ranges from 400 to 600 ft. The innerburden averages 105 ft. The immediate roof above the Upper Kittanning Coalbed consists primarily of a gray shale, at times grading to a sandy shale or sandstone. The remaining overburden is a mix of shales, sandy shales, sandstones, fireclays, and coal. Immediately below the Upper Kittanning Coalbed is a limestone floor (6 pct of the innerburden). The remaining innerburden is composed of 44 pct shale, 25 pct sandy shale, 19 pct sandstone, 4 pct fireclay, and 2 pct coal. The Lower Kittanning Coalbed averages 5 ft thick. Extraction heights range from 52 to 72 in, again depending on roof conditions.

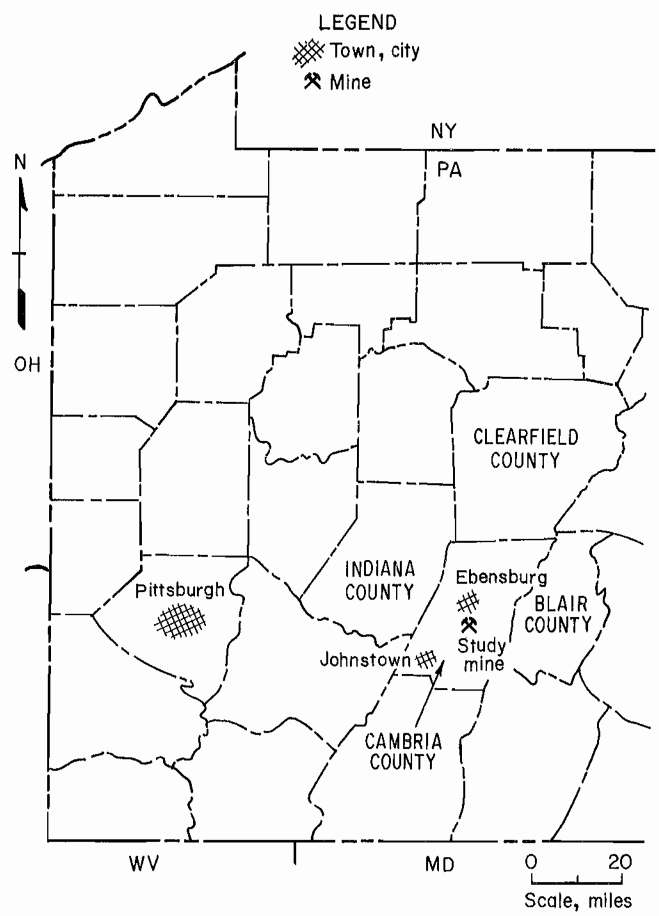

Figure 2.—Location of study mine.

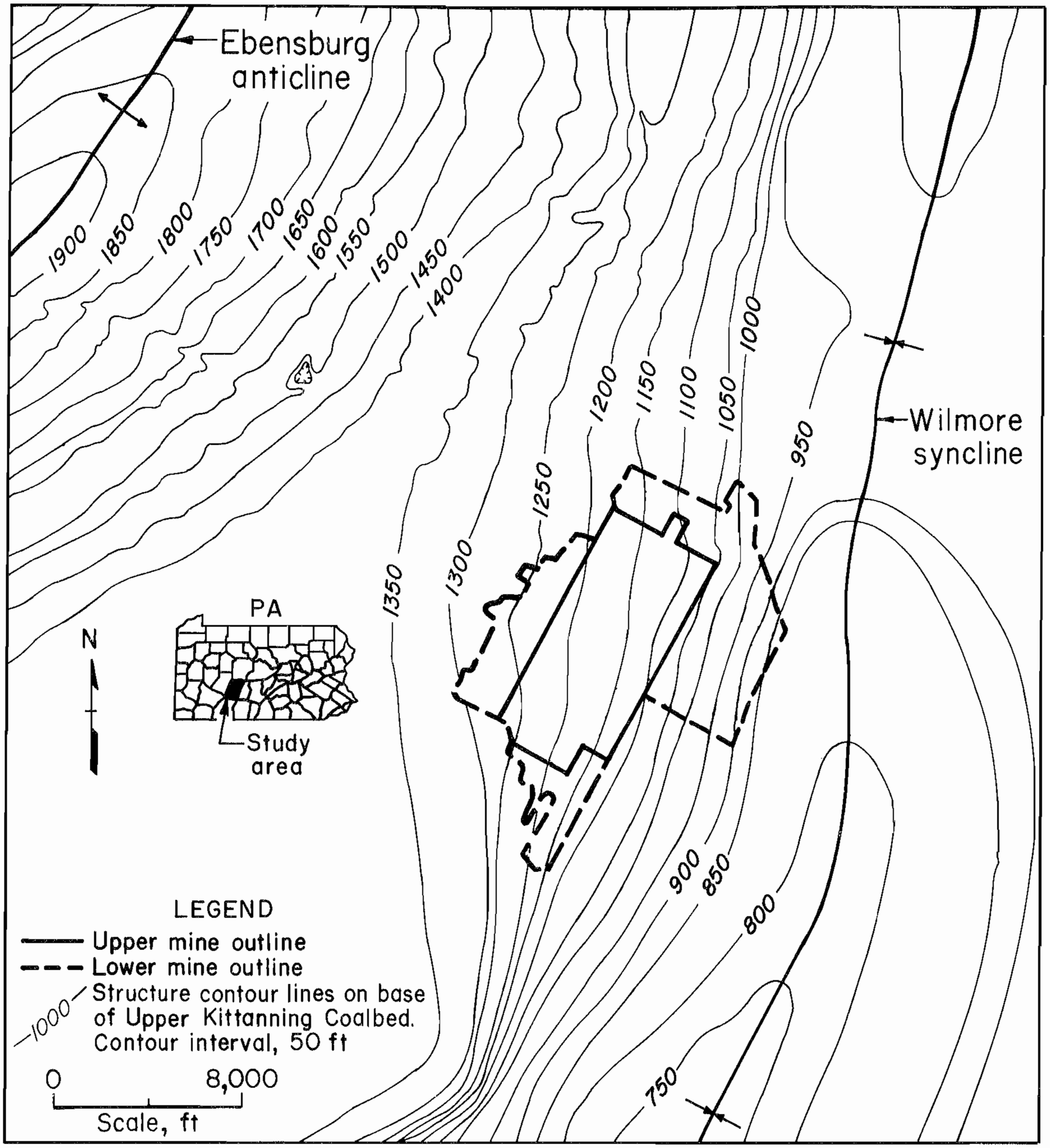

Figure 3.—Map of upper and lower mine boundaries.

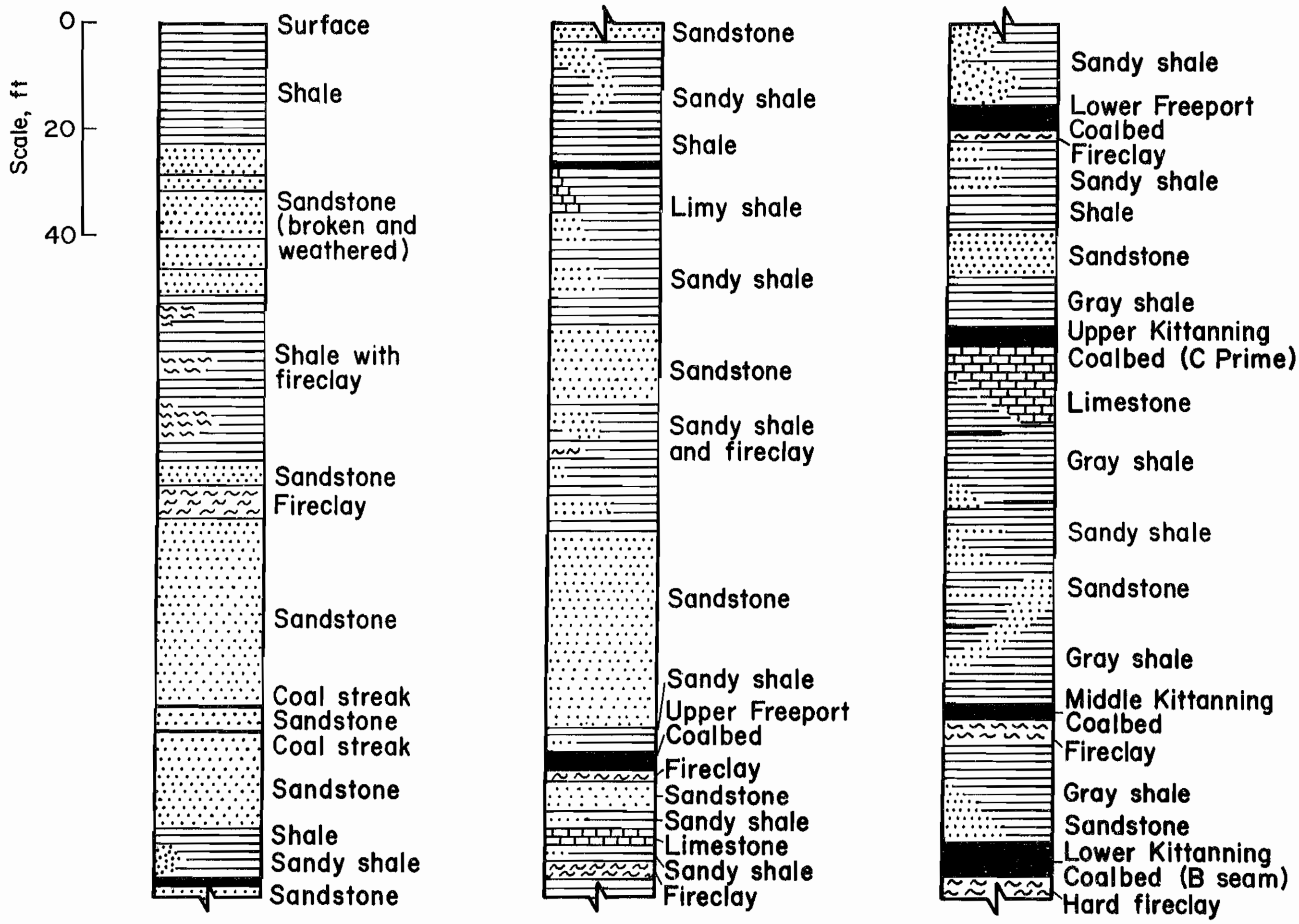

Figure 4.—Stratigraphic column for study site.

PREDICTED INTERACTION

Prior to beginning the field study, a prediction of the interactions that may occur because of undermining in the lower coalbed was attempted. Researchers such as Zhou and Haycocks (*9*) have shown that if sufficient information on the geologic and mining factors is known, the interactions can be estimated with reasonable accuracy. Of particular importance in analyzing interactions is the mining scenario present. The situation at the study mine is classified as a "passive mining condition," in which undermining is complete and the ground has settled, reaching a new equilibrium. This passive mining condition allows for a more accurate prediction, since no additional innerburden interactions will occur as the upper coalbed is mined because the ground has completely settled.

Initially, some general predictions can be made based on past Bureau research, case study analyses, and information on current mine conditions. Since no serious ground control problems were encountered in the past when superpositioned gate roads were developed in the upper mine (unless mining occurred over virgin lower coalbed), the analysis should show stable conditions in the gate roads. Also, previous research has documented that ground control problems occur when mining across lower mine gob, especially in the boundaries of the subsidence trough. Ground control problems should be encountered in these areas in the upper mine, and should be predicted by the analysis.

The Damage Factor Method can be used to predict the multiple-seam subsidence interactions. This method was developed by Webster, Haycocks, and Karmis (*16*) and presented by Zhou and Haycocks (*9*). Two equations are used to calculate damage factors that predict the likelihood of unstable ground conditions in upper coalbeds (*9*). The damage factor without considering the composition of the innerburden is represented by the following equation:

$$DF = 620 + 0.5Y - 9.42X, \quad (1)$$

where DF = damage factor,

Y = (innerburden thickness, ft, divided by lower seam height, ft) multiplied by (time lapse after mining lower seam, years),

and X = percent extraction.

To adjust for the effect of sandstone in the innerburden, equation 1 becomes

$$ADF = DF + (Z - 50), \quad (2)$$

where ADF = adjusted damage factor,

and Z = percent sandstone in innerburden.

A positive DF or ADF indicates that no appreciable damage is anticipated in the upper coalbed (*9*).

For the study mine, the following information is used in equations 1 and 2 to calculate the damage factor for both gate road development and across-gob mining:

Extraction of lower seam:		
Gate road development	pct	38
Across-gob mining	pct	100
Innerburden thickness	ft	105
Lower seam height	ft	5
Time lapse after mining lower seam	years	11
Sandstone in innerburden	pct	19

Solving equations 1 and 2 for gate road development gives a DF = +378 and an ADF = +347, indicating that no ground problems should occur in the gate road developments as a result of multiple-seam mining interactions. For mining across lower mine longwall gob, equations 1 and 2 give a DF = -207 and an ADF = -238, a clear prediction that problems will occur in these areas.

DESCRIPTION OF FIELD STUDY

The study was conducted at six sites in the Upper Kittanning Coalbed (fig. 5). Geological, physical, and observational information was collected on ground control problems resulting from subsidence induced by multiple-seam mining. Four sites were located in perpendicular-to-panel mine areas. The remaining two were in parallel-to-panel mine areas. Although the ground conditions were similar for both parallel- and perpendicular-to-panel areas, the different mining scenarios led to this grouping as the most efficient manner for describing the study.

PERPENDICULAR-TO-PANEL MINE AREAS

The study areas labeled perpendicular-to-panel are simply those that were driven from one gate road to the other, and across longwall gob from the lower mine. Developed for use as either longwall setup entries or recovery rooms, the areas were never fully utilized as intended and were not affected by longwall panel extraction in the upper mine. The four mine areas investigated were 1-2 Right, 5-6 Left, 6-7 Right, and 6-7 Left, all off 4 West Mains.

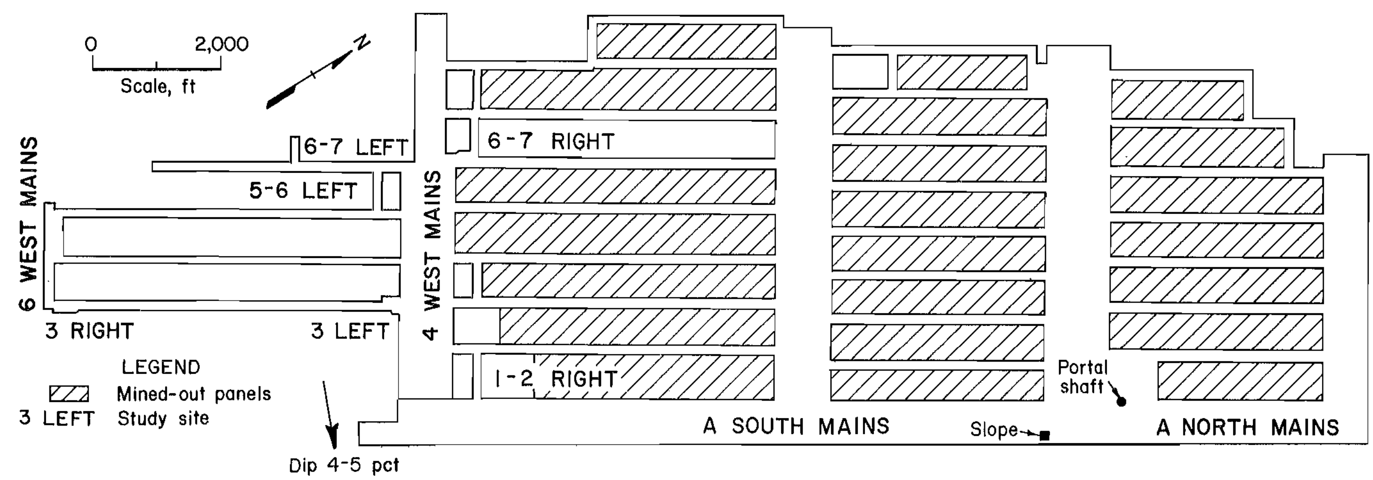

Figure 5.—Map of study sites in Upper Kittanning Coalbed.

Similar ground conditions were experienced in the four test sites, including bad roof and water inflow. Figures 6 through 9 show the four test sites, the geologic and deformational conditions encountered, the relative superpositioning of upper and lower mine gate roads, and the location of lower mine gob. Only small areas of bad roof were encountered; these areas caused negligible problems. Usually, joints and clay veins accompanied the bad roof (fig. 10). Interestingly, the areas of bad roof were not the same areas that experienced the massive water inflows. These areas were in close proximity, but did not overlap. The bad roof areas were controlled through installation of longer bolts in conjunction with bacon skins (lighter gauge steel straps), steel channels, and posts (fig. 11).

The major problem encountered was the water seeping or gushing from the roof. Massive inflows of water from the mine roof began within 10 to 25 ft after crossing the lower panel gob line. As little as a trickle to as much as 0.62 gal/min of water was flowing out around roof bolts and from fractures in the roof. Most water stopped within a distance of 70 ft after crossing the gob line, but in 6-7 Left, water flow continued for nearly 170 ft.

Common sense would predict that a mirror image of these problems would be encountered when mining back over the gob line and into the superpositioned gate roads. However, this only occurred at one of the sites, 5-6 Left off 4 West. A second site, 6-7 Left off 4 West, was not completely driven from one gate road to the other, so no determination of a mirror image could be made. In the two areas on the right side of 4 West, 1-2 Right and 6-7 Right, most of the ground problems, including water, were found on the downdip side only. Several hypotheses can be made for why a mirror image of problems did not occur, especially the presence of water, including the following:

1. The time between mining and investigation was more than a few years,
2. All mining took place updip, and
3. The updip side was adjacent to same-seam longwall panel gob.

Any one or a combination of these factors could be responsible for eliminating or redirecting the water so that none was present in the updip areas at the time of the investigation.

PARALLEL-TO-PANEL MINE AREAS

The remaining two test sites, 3 Right and 3 Left, were part of the same gate road, but located at opposite ends (fig. 5). Describing these areas as parallel-to-panel simply means that the entries in question were driven out over the gob, but parallel to the gate road. These entries were intended to provide additional airways or travelways and, in the case of 3 Right, to circumvent a roof fall that rendered a planned entry unusable.

Ground conditions in these areas were less than ideal, with bad roof and water as the predominant obstacles to mining. In 3 Left off 4 West (fig. 12) the mine areas out over the gob experienced large inflows of water over most of their lengths. Inflows as high as 0.78 gal/min were measured (fig. 13). The bad roof areas were controlled by installing longer bolts and steel channels, as well as posts and cribs where needed. These entries were abandoned because of the problems encountered.

In the 3 Right off 6 West area (fig. 14), considerable ground problems were present that seemed to be unrelated to the presence of lower coalbed gob. Cutter roof failure and a banded shale and sandstone immediate roof were found throughout the area; these factors appeared to be the main initiators of the bad roof and roof falls that occurred (fig. 15). Some bad roof was found in the entry driven out over the gob (lower side of gate entries), but no water was present. The only areas where water inflows were located were the butt entries driven from the upper gate entry out over lower mine gob. Although they were only mined to a depth of 15 ft, many showed evidence of varying amounts of water. Water in one of the butt entries was flowing at a rate of 1.17 gal/min.

IMPLICATIONS FOR FUTURE MINE DEVELOPMENT

The most efficient sequence of extracting multiple coalbeds is to mine from the top down. At the study site this would entail mining the Upper Kittanning Coalbed first, extracting as high a percentage of the coal as possible, then mining the Lower Kittanning Coalbed, superpositioning the workings. Unfortunately, previous mining of the Lower Kittanning Coalbed precludes mining in this manner. Also, mining the upper coalbed first may not be ideal since severe ground conditions were encountered in the upper coalbed when mining over virgin lower coalbed (presumably the result of high horizontal stress).

Given the location of past and current workings of both coalbeds and the relative success of superpositioning, mining should continue using this method of extraction. Near 100-pct extraction of the lower coalbed should be practiced, and gate roads and longwall panels in the upper coalbed should continue to be superpositioned over similar lower mine workings. One practice to be avoided is the driving of upper mine workings over lower mine gob. Although ground conditions vary significantly and mining through these areas is possible, this practice could subject mine workers to hazardous conditions.

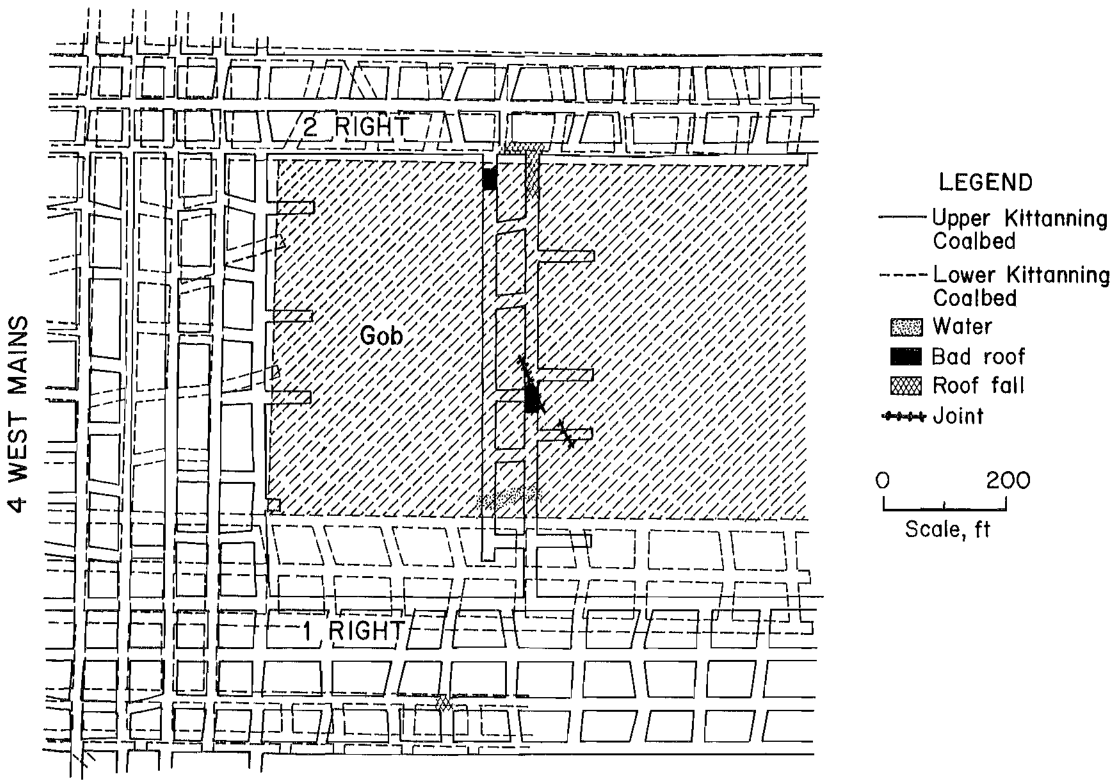

Figure 6.—Geologic and deformational map of 1-2 Right off 4 West.

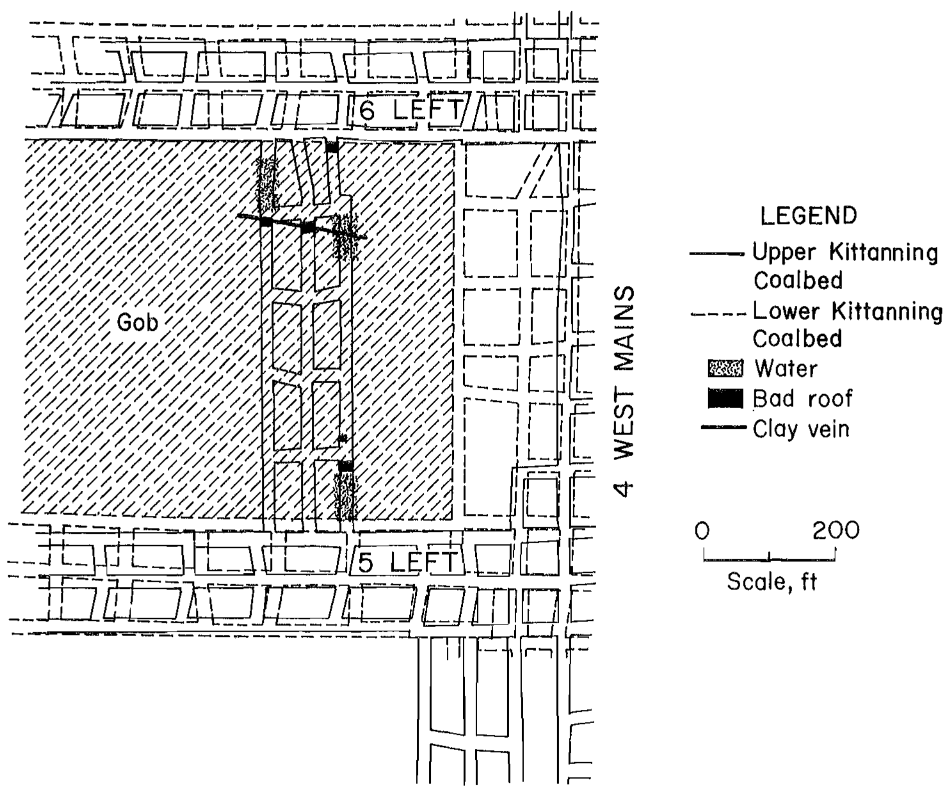

Figure 7.—Geologic and deformational map of 5-6 Left off 4 West.

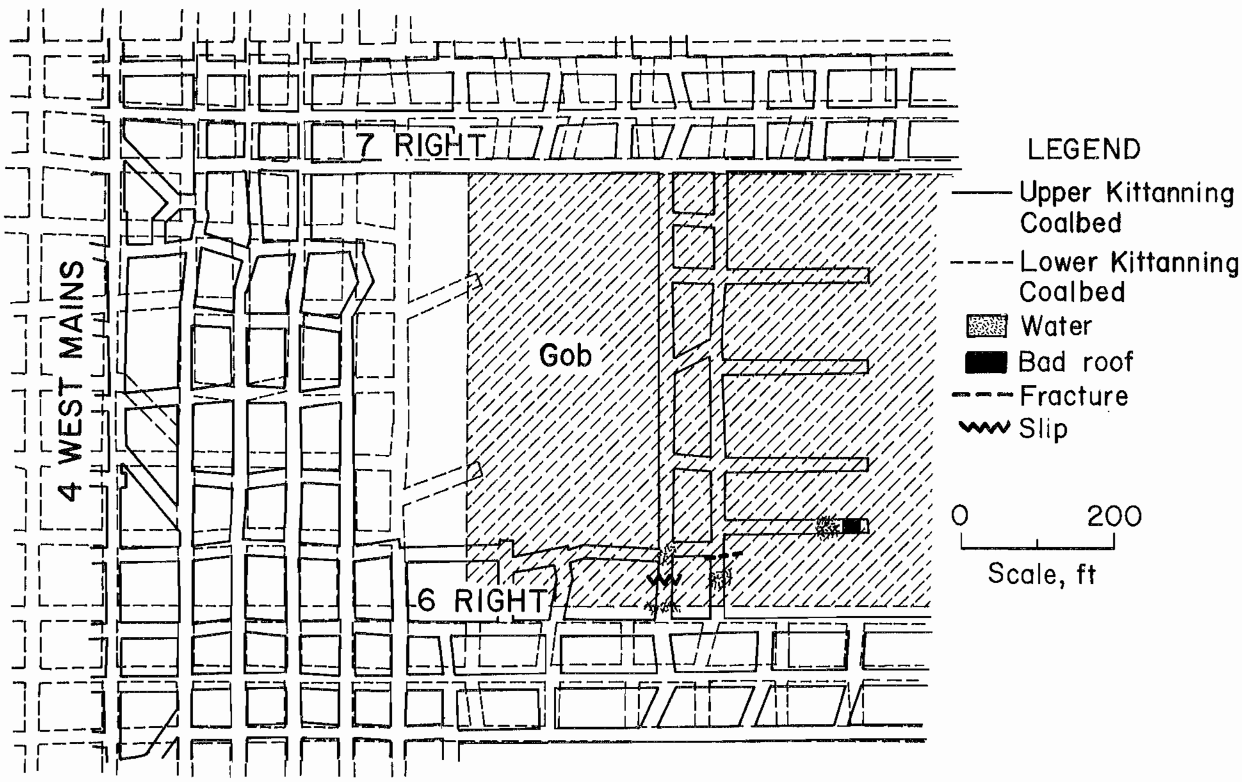

Figure 8.—Geologic and deformational map of 6-7 Right off 4 West.

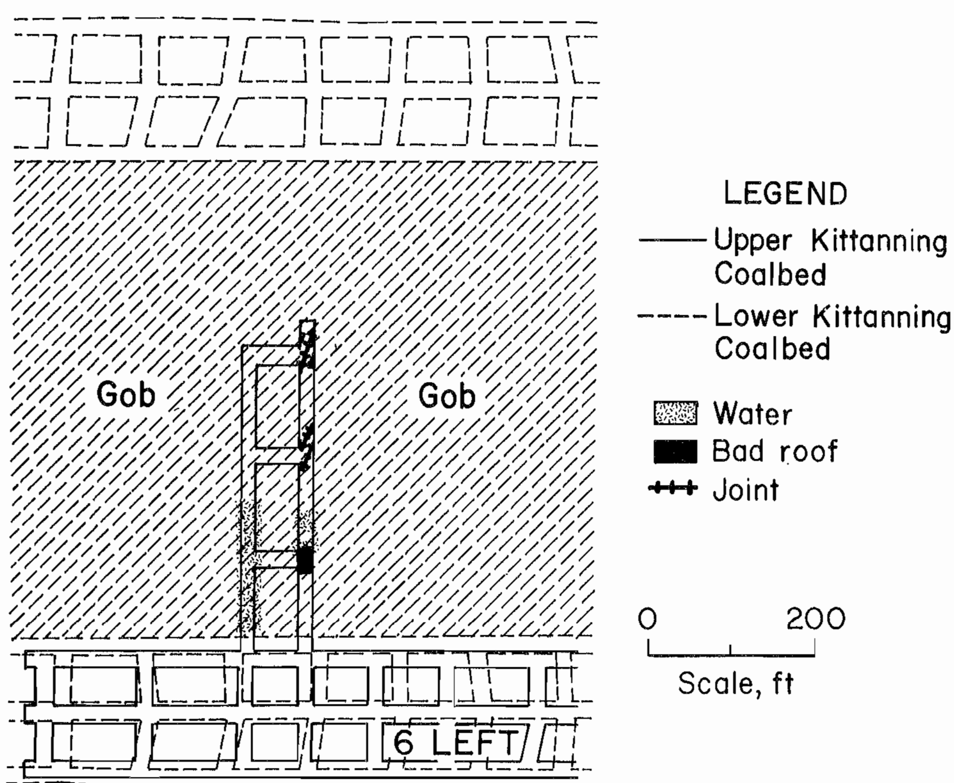

Figure 9.—Geologic and deformational map of 6-7 Left off 4 West.

Figure 10.—Bad roof conditions associated with jointing.

Figure 11.—Supplemental support of bad roof areas.

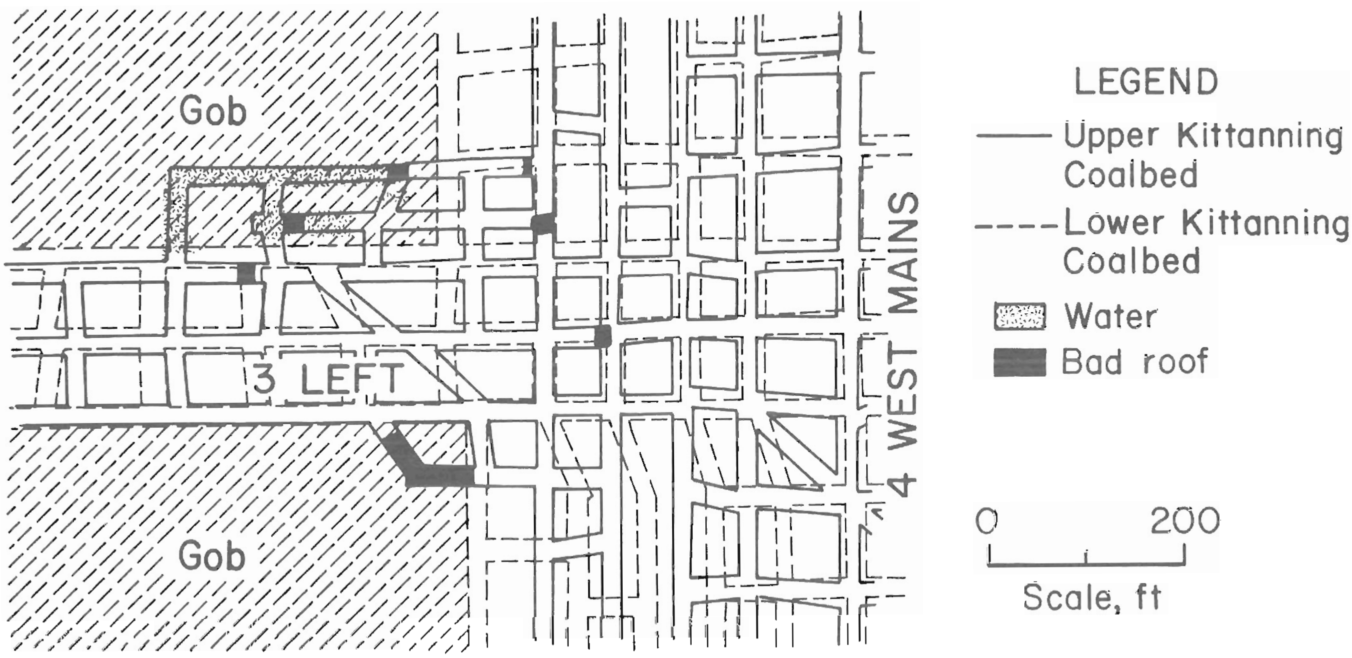

Figure 12.—Geologic and deformational map of 3 Left off 4 West.

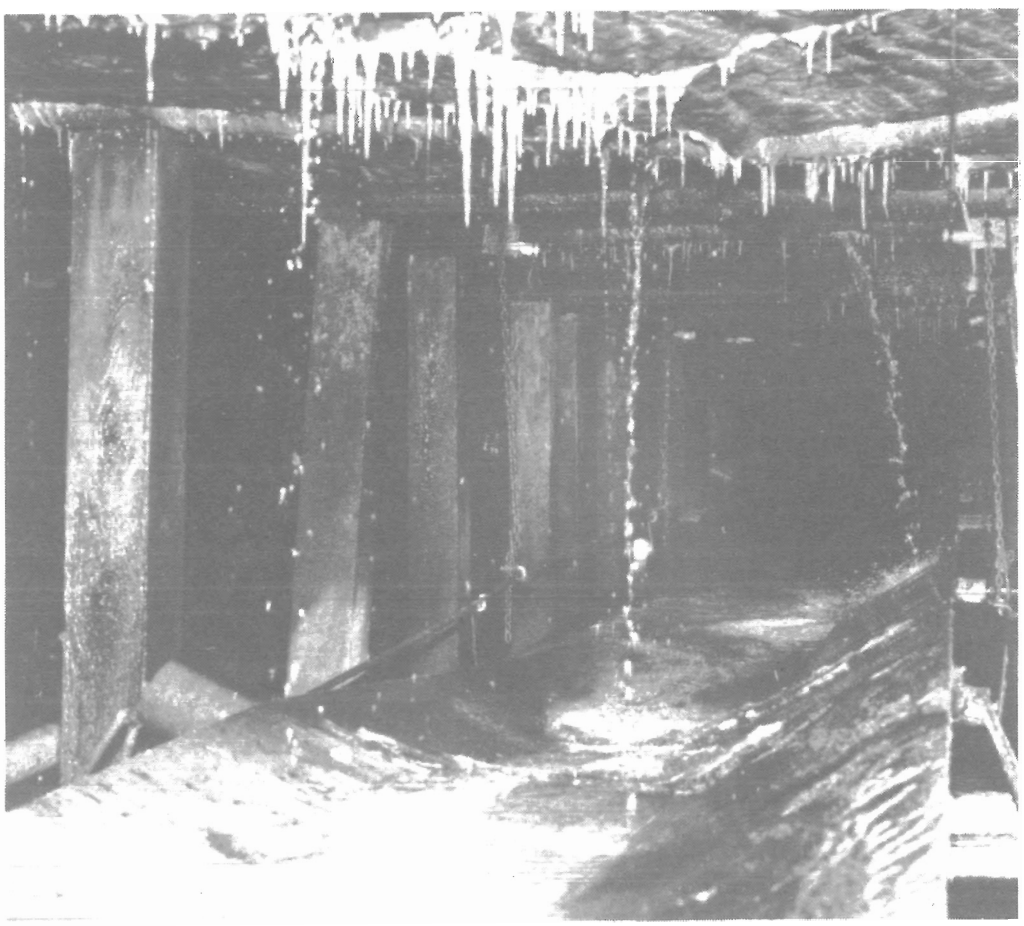

Figure 13.—Water inflows from mine roof.

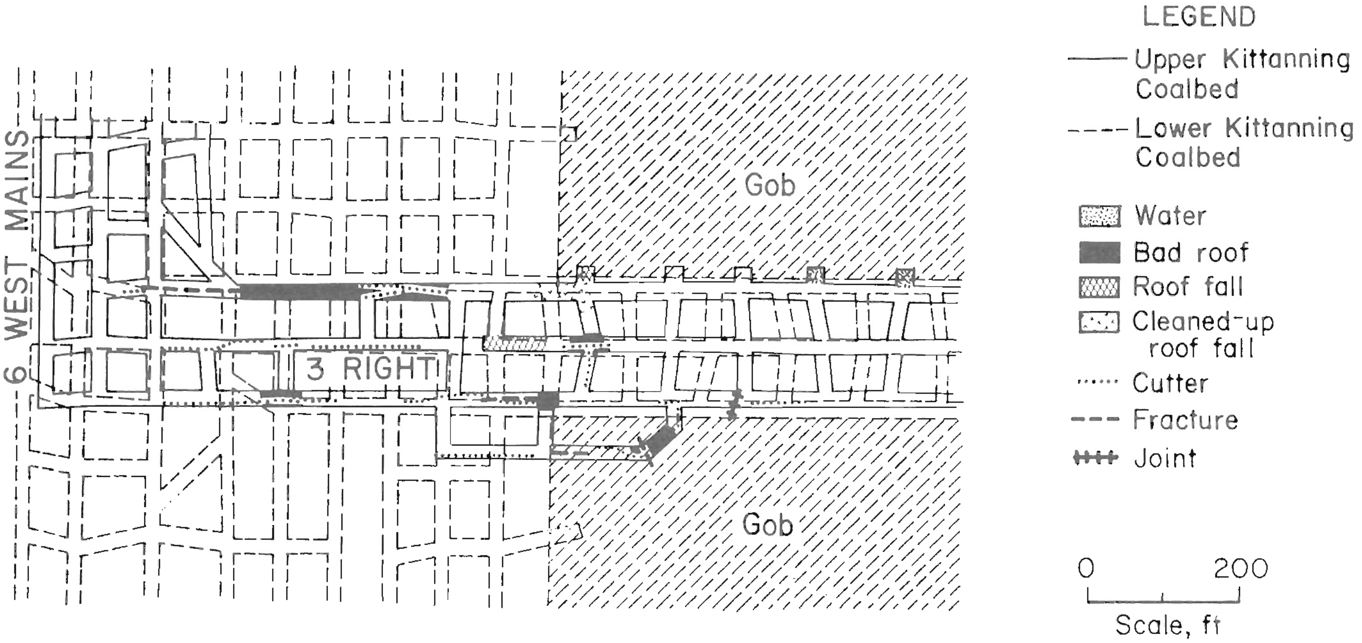

Figure 14.—Geologic and deformational map of 3 Right off 6 West.

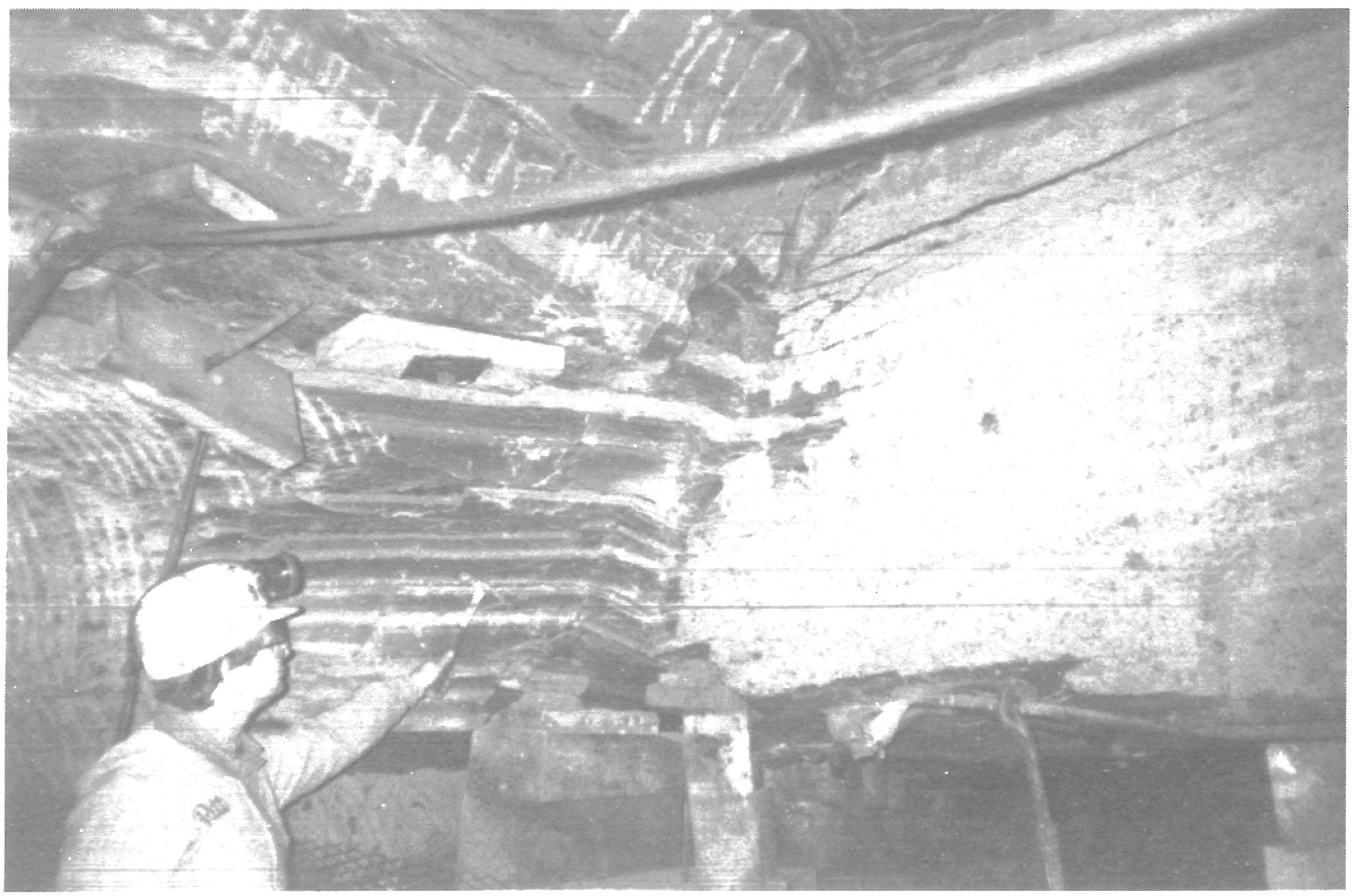

Figure 15.—Cutter roof and banded roof rock.

DISCUSSION AND CONCLUSIONS

In the U.S. mining industry there are times when situations dictate mining with less-than-optimal methods. This is the case at the study mine. Past mining in the lower coalbed has forced the use of a mining system that, although effective, is not the optimal system. Ground hazard prediction using the Damage Factor Method, coupled with underground observations, has provided insight as to the multiple-seam interactions that can be expected. Mine management used this information, adapting it to the conditions present, to produce coal despite the less-than-ideal mining situation. Continuing to mine in a similar manner, while altering mining as conditions warrant, will ensure continued improvement in productivity and worker safety.

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☆ U.S. GOVERNMENT PRINTING OFFICE: 1992--611-208

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