CAUSES AND CONTROL OF COAL MINE BUMPS

By Claude A. Goode,[1] Anthony Zona,[2] and Alan A. Campoli[3]

[1]Supervisory Mining Engineer, Pittsburgh Research Center, Bureau of Mines, U.S. Department of the Interior, Pittsburgh, PA.
[2]Supervisory Mining Engineer, Roof Control Division, Mine Safety and Health Administration, Pittsburgh, PA.
[3]Mining Engineer, Pittsburgh Research Center.

INTRODUCTION

A coal bump or burst in a coal mine is defined as the instantaneous violent failure of a coal pillar(s) from overstress. The causes of coal bumps are not well understood. In some bump-prone seams, minor disturbances are a daily occurrence. Lack of knowledge about coal bumps coupled with questionable mining practices can create disastrous bump situations.

Reportable bumps are defined by MSHA as those that cause disruption in the mining operation for more than one hour or result in injury or death. It is often difficult to ascertain whether or not some bumps are masked by other events. For example, a gas release triggered by a bump may ignite, and the event is reported as an explosion. Therefore, the relatively few occurrences that are reported probably represent a conservative number. Given the consequences of bumps in terms of pain and suffering, property damage, and production delays, this problem must be taken seriously. Further, as one of the major factors causing bumps is seam depth, this problem will increase as shallow reserves are depleted, requiring the mining of deeper seams.

Much of the early work on bumps was documented by U.S. Bureau of Mines researchers and operators of mines prone to bumps. In 1954 the Bureau of Mines published Bulletin 535, "Coal Mine Bumps: Some Aspects of Occurrence, Cause, and Control," by C. T. Holland and E. Thomas. The report analyzed the the occurrence and causes of coal bumps that had occurred over a 25-year period. It is the purpose of this paper to compare recent events with these findings and to suggest measures that can be taken to minimize the potential occurrence and severity of coal bumps.

ACCIDENT STATISTICS

The coal bump problem continues to present a hazard to the mining industry in certain areas of the United States. Records show that in the past 25 years the coal industry suffered 28 fatalities due to bumps (table 1); 14 of these were in 4 Eastern States and 14 were in 2 Western States. Table 2 shows that from 1978 through 1983 there were 73 reportable accidents attributable to pressure bumps and bursts. Of these, 75 percent were without injury. The same six States were involved.

Table 3 is a synopsis of bump fatality reports over the last 20 years. The geological conditions indicated in the table reinforce the observations made by Holland and others, that the natural conditions that favor bumps in coal mines are 1) the cover over the

TABLE 1. - Fatalities attributed to bumps in coal mines.

	STATE	YEAR																								TOTAL
		1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	
EAST	VIRGINIA									1							1			1							3
EAST	WEST VIRGINIA						1	1	1			1									1					3	8
EAST	KENTUCKY					1		1																			2
EAST	PENNSYLVANIA		1																								1
EAST	TOTAL		1			1	1	2	1	1		1					1			1	1					3	14
WEST	COLORADO									1		2						2		1		2			1		9
WEST	UTAH	1	1				2						1														5
WEST	TOTAL	1	1				2			1		2	1					2		1		2			1		14
	GRAND TOTAL	1	2			1	3	2	1	2		3	1				1	2		2	1	2			1	3	28

TABLE 2. – Accidents attributed to bumps.

[Title 30 Code of Federal Regulations Part 50.2(h)(9)]

	STATE	YEAR						TOTAL
		78	79	80	81	82	83	
EAST	VIRGINIA	4	5	9	2	1	1	22
EAST	WEST VIRGINIA	2	1	3	1	0	7	14
EAST	KENTUCKY	1	1	0	1	1	1	5
EAST	PENNSYLVANIA	2	0	1	0	2	0	5
EAST	TOTAL	9	7	13	4	4	9	46
WEST	COLORADO	0	2	5	9	2	1	19
WEST	UTAH	1	1	0	1	4	1	8
WEST	TOTAL	1	3	5	10	6	2	27
	GRAND TOTAL	10	10	18	14	10	11	73
	WITHOUT INJURY	6	6	16	11	8	8	55

TABLE 3. – Description of areas where pressure bumps have resulted in fatalities.

Date	State	Seam	Cover (ft)	Coal thickness (in)	Roof		Floor	
					Thickness (ft)	Description	Thickness (ft)	Description
11/29/83	WV	Chilton	752	42	55	Sandstone	- 2	Sandstone Shale
10/18/83	WV	Pocahontas 4	935	72	60	Massive sandstone		Massive sandstone
8/12/82	UT	Blind Canyon	1,400	168	- 2	Sandstone Laminated shale		
12/8/78	WV	Pocahontas 4	1,475	84	200	Massive sandstone	- 2	Massive sandstone Shale
4/27/78	CO	Sub-seam No. 3	1,400	72	- 1-1/2	- Sandy shale	90	Hard sandstone
11/4/77	VA	Tiller		120		Hard shale and sandstone		
10/4/77	CO	Middle B	2,850	108				
5/23/75	CO	Coal Basin B	2,000	84		Hard sandstone		Weak bottom--shale, coal
5/15/74	VA	Pocahontas 3	2,400	56	60 25	Massive sandstone Sandy shale		Sandy shale
4/14/70	UT	Castle Gate D	1,500	150		Firm sandstone		Sandy shale
11/6/69	WV	Cedar Grove		72	40	Sandstone		Dense fireclay
10/3/69	CO	Coal Basin B	2,300	84		Sandstone		Coal
8/29/69	CO	Coal Basin B	2,000	84		Laminated shale		Soft shale and coal
12/13/67	VA	Tiller	1,100	54	25	Medium-grained sandstone		Hard dense shale and siltstone
1/11/67	CO	"C" coalbed	1,500	84		Coal-bearing shale, laminated shale, and sandstone		Laminated shale and sandstone
1/31/66	WV	Pocahontas 4	750	80	20 2	Sandstone Shale	- 5	Sandstone Sandy shale
9/2/65	WV	Pocahontas 4	1,000	60		Massive sandstone	- 4	Massive sandstone Sandy shale
8/12/65	KY	Harlan	1,500	50		Massive sandstone		Dense shale
6/3/64	UT	Sunnyside	2,000					
2/25/64	WV	Eagle	845	53		Massive sandstone		Dense shale

coalbed is 500 feet or greater, 2) the stratum immediately above the coalbed are generally massive sandstone, and 3) the stratum underlying the coalbed are usually strong and do not heave readily. Additionally, discontinuities in the strata such as faults may contribute to bump occurrences when the first three conditions are present.

In those reports where the information was available, 100 percent of the occurrences met the depth criterion, 90 percent met the sandstone roof criterion, and 80 percent met the floor criterion. Although the data in these reports are incomplete to sparse and represent a very limited data base, they appear to reinforce the observations of Holland in his examination of 117 incidents during the period 1925 to 1950. The data also support the observation that more complete geological and rock property information is needed if the bump phenomenon is to be better understood.

PILLAR LOADING

Coal measure rock properties are variable and change over short distances both laterally and vertically. However, if it is assumed that coal measures are perfectly elastic, homogeneous, and isotropic media, simple theoretical models can be developed that can be used in analyzing rock behavior around underground openings. These idealized concepts when tempered with actual underground observations and measurements not only lead to a better understanding of ground structure but also provide insight as to remedial steps that might be taken to improve ground control.

When an opening is developed in coal, a portion of the roof support is removed, and the load in the roof over the mined-out area must be carried by the coal that remains. The floor also reacts to that added load through the coal. Across the opening the tendency is for the roof to deflect and fall and for the floor to heave. Further, the confined coal tends to move laterally into the opening, resulting in a wider opening, which transmits an additional load to the remaining coal. Figure 1a illustrates the adjustment of the stress field to the loss of equilibrium and the creation of high loading at the edge of the coal due to stress concentration. Figure 1b is a graphical interpretation of the stress distribution.

The load transferred to a pillar is determined by the portion mined and the weight of the overburden. The stress distribution in the pillar, however, is determined by the physical properties of roof, floor, and coal. The probable stress distribution on a wide pillar is shown in figure 2. As illustrated, the assumption is that the pillar has enough roof contact area to carry the load without failure and enough bearing area to resist the load. It is further assumed that the roof and floor are unyielding. Since coal generally is a brittle material, the stresses are low at the edges of the pillar and increase rapidly over a short distance into the pillar. The state of stress in the center of the pillar is probably a function of the width and time. In a wide pillar it is postulated that the stress level is substantially lower in the pillar core than near the edges.

Figure 3a indicates the stress pattern over a narrow pillar. As a narrow pillar takes load, the roof and floor tend to converge and the pillar yields. Under this condition, the yield pillar is incapable of carrying subsequent loadings, as a result solid coal bears the additional weight. The formation of a secondary arch as shown in figure 3b is time dependent, being a function of the nature of the strata.

Unlike the assumed model, most coal mine roofs are composed of layered shales, the coals are relatively soft with persistent fracture planes, and the floors are fire clay or soft shale. Given that variable composition, the weakest link in the system will fail while the other members will adjust until the system regains equilibrium. Caving, heaving, squeezing, and/or

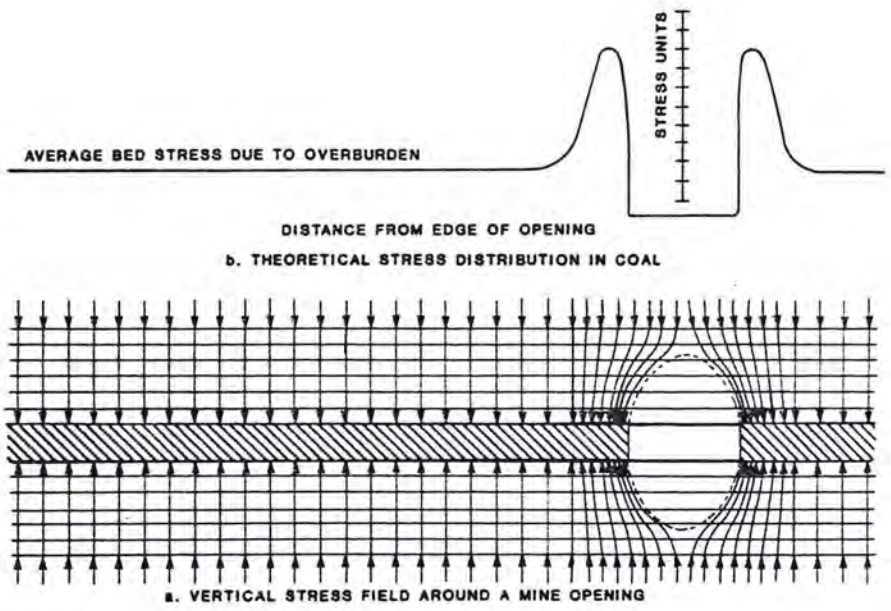


FIGURE 1. - Representations of stress distribution around a mine opening.

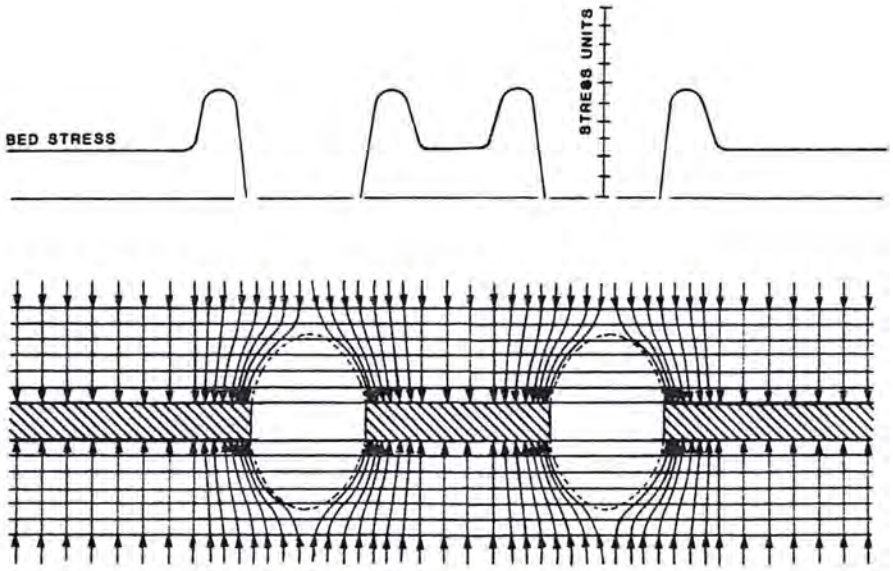
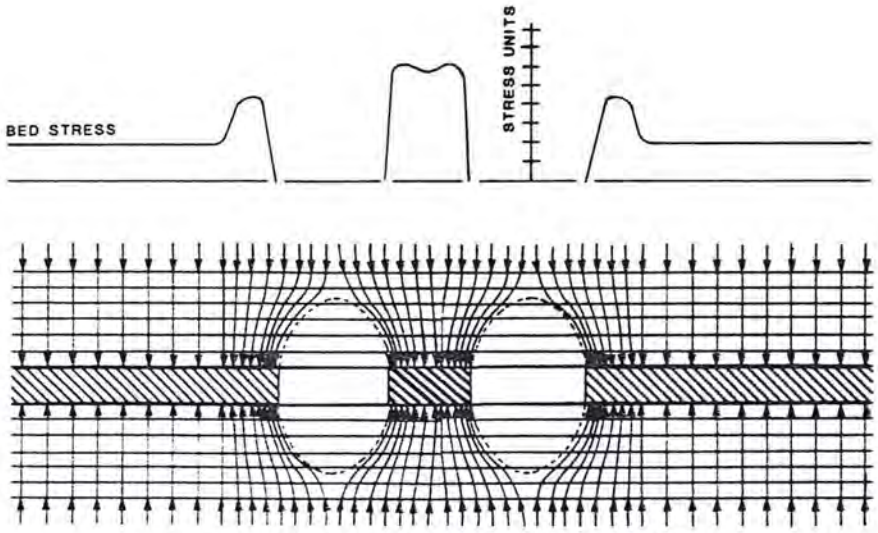
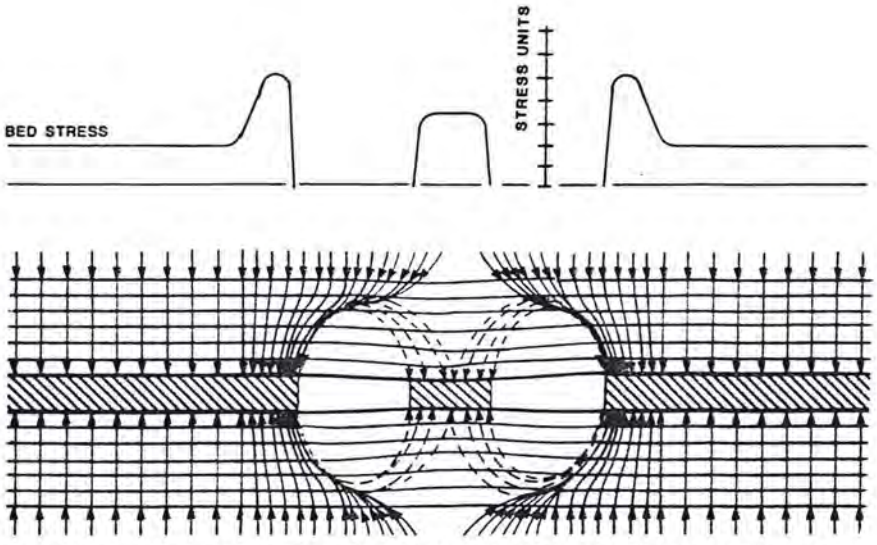


FIGURE 2. - Stress distribution over a wide pillar.



a. NARROW PILLAR PRIOR TO SQUEEZING UNDER HIGH LOADING



b. NARROW PILLAR IN YIELD UNDER HIGH STRESS WITH SOLID COAL UNDER ADDITIONAL LOAD

FIGURE 3. – Stress readjustments over a narrow pillar.

pillar punching are manifestations of this adjustment. In coal pillar extraction areas where thick, weak strata exist above and/or below the seam, bumps rarely occur. In other words, a good break of the roof or floor reduces roof loads on the pillar line. Observations by numerous investigators support this conclusion (2)(3)(4).

PRESSURE BUMPS

There is no single cause of bumps other than failure within the roof-coal-floor system. A bump is the manifestation of the reaction of the coal to the initial failure of one of these members. A bump is classified as a pressure bump when a pillar(s) reaches its maximum load-bearing capacity. The load may be caused either by a hanging roof or by a rigid floor. If neither the roof nor the floor breaks to relieve the abutment pressure, the pillar could load excessively. The coal pillar generally reacts by gradual failure through crushing. Some coals, like the Pocahontas No. 4, tend to compress and dilate. This tendency for lateral displacement is resisted by the friction between the coal and rock. With sufficiently high vertical pressure, these friction forces are overcome and the coal is violently projected from the pillar by the release of this stored energy.

Figure 4 illustrates the conditions that resulted in an actual pressure induced bump. A barrier block was being developed using the "narrow room method." To reduce the bump potential, No. 2 room was driven to create a chain pillar the same size as the outby pillar. This was done in an attempt to gradually release any stored energy. Bump cuts had been made in the large block to allow for stress relief should the pillar bump. At the time of the bump, which resulted in a fatal accident, the continuous miner was positioned in No. 5 room but was not cutting coal. Bolting was in progress in the No. 1 pillar split.

The barrier block was reduced to a size that would no longer support the abutment pressures from two pillar lines. The coal was being mined under 1,000 feet of cover between a massive sandstone roof and floor. The relatively soft coal stored a tremendous amount of elastic energy before lateral failure occurred. It is hypothesized that the forces acted as shown in figure 5.

In old workings where pillars are being mined, coping with abutment pressures is difficult. Attempts to stress-relieve potential areas of high stress should be made in advance of the pillar line abutment zone. This is essential if the occurrence and severity of coal bumps are to be reduced.

SHOCK BUMPS

A bump is classified as a shock bump when sudden failure of the roof or floor results in an impact load on the pillar. The roof and floor that span a mined-out area can also store strain energy. The amount of energy stored is a function of the length of the span and whether it is acting as a beam, fixed on both ends, or as a cantilever. A cantilever beam stores about 36 times the energy of a fixed beam of the same length (3). When such a thick rigid member fails, it can deliver a violent hammer-like blow to the coal.

Figure 6 graphically illustrates the development of an actual shock bump that resulted in a fatal accident. The layout of the panels and the sequence of mining were designed to minimize the occurrence of bumps. All of the classic elements leading to bumps were there; the cover was 1,100 feet, the roof had changed from laminated shale and sandstone to a thick sandstone, and the floor was a hard dense shale that resisted heaving. Under these conditions, the barrier pillar between No. 5 entry of panel 7 and No. 1 bleeder entry of the previously mined panel 6 was developed a sufficient distance outby the extraction zone to equalize the stress on the coal pillars in the pillar line point area. The pillar mining plan required that the pillars be extracted individually in succession from right to left to establish a flat pillar line. The No. 1 entry bleeder

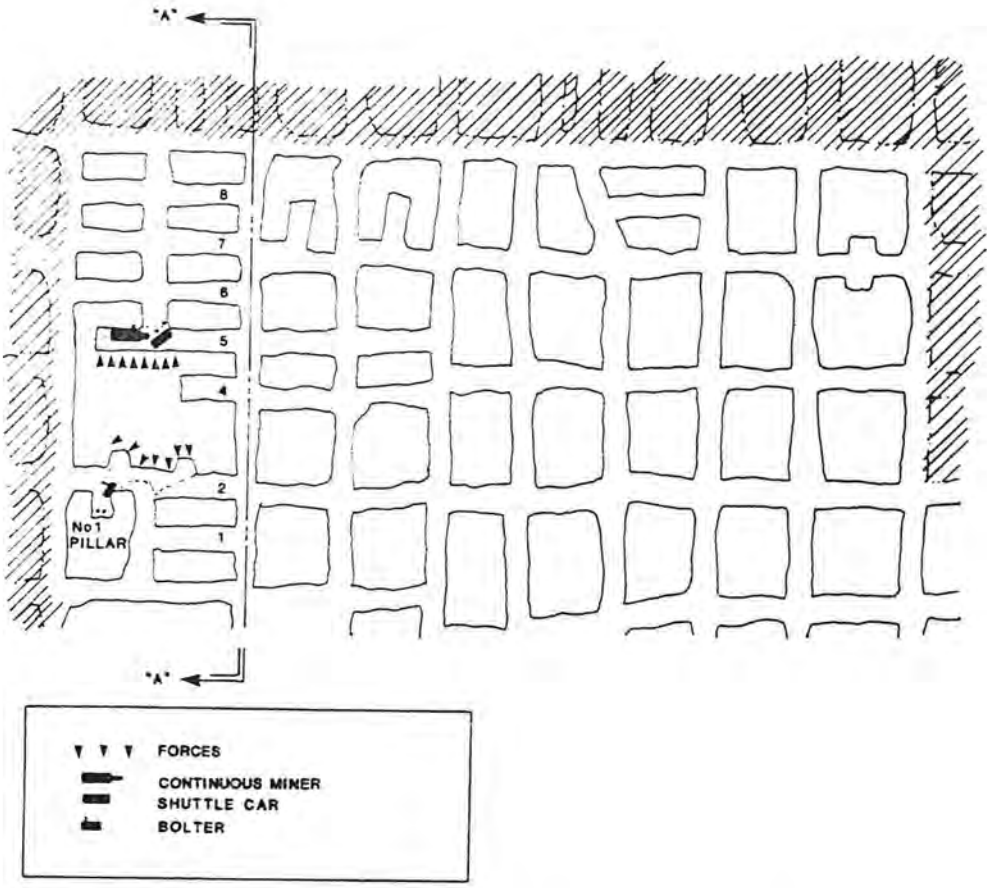


FIGURE 4. – Pressure bump occurrence as the result of reducing a barrier pillar to a critical size.

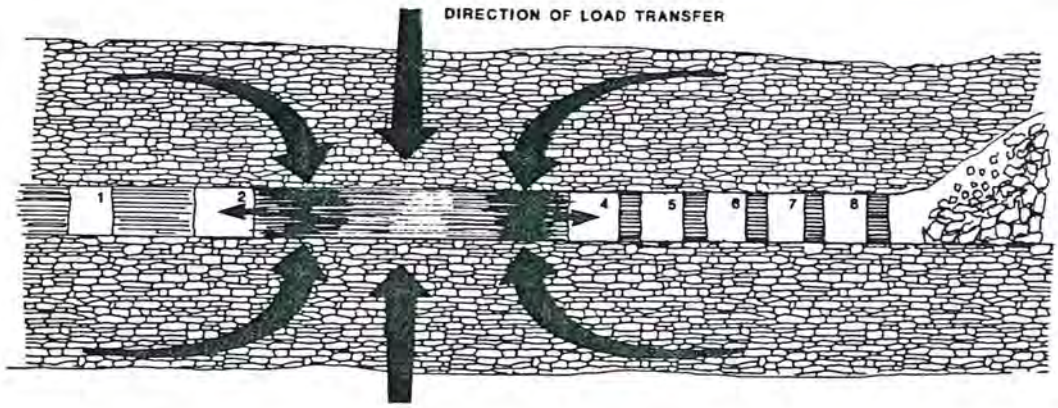


FIGURE 5. – Idealized illustration of Section A–A of FIGURE 4.

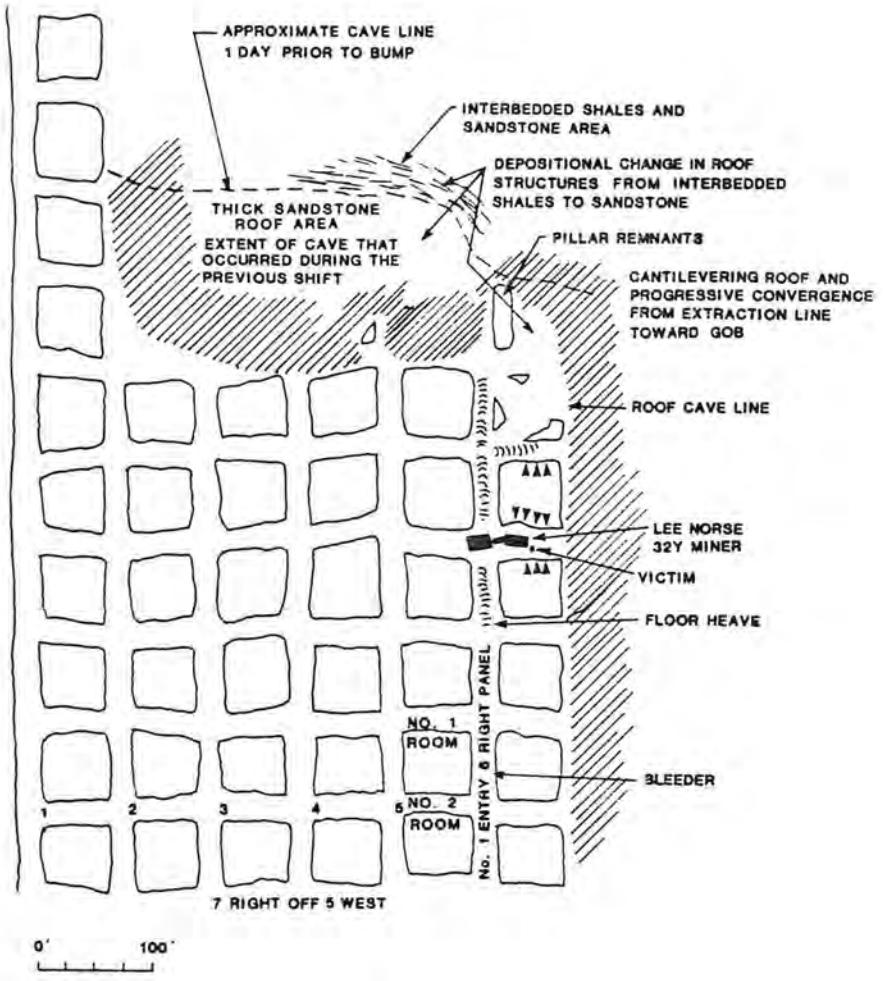


FIGURE 6. - Shock loading due to failure of pillar remnants.

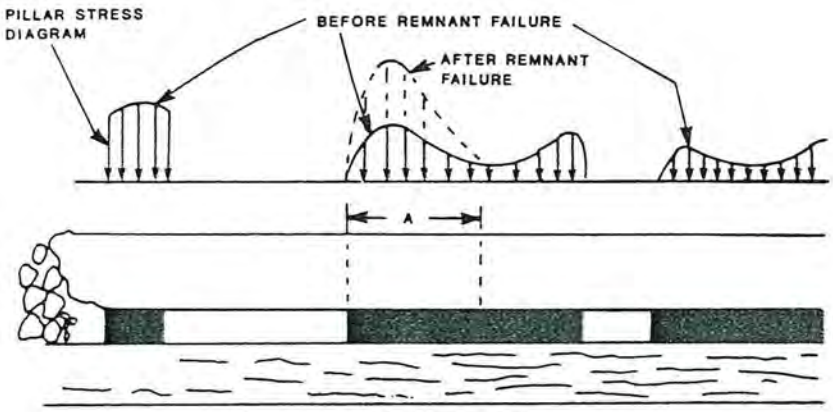


FIGURE 7. – Shock bumps in coal beds (2).

block was mined in advance of the pillar line to permit the roof to break against the previously mined panel. The system was considered successful. Unfortunately, large pillar remnants were left in the gob inby the No. 1 pillar, which impeded a clean roof break. Instead of crushing, the remnants carried load so that when they did fail, a shock bump was initiated in the active pillar area. The failure conditions were of the type shown in figure 7.

SUMMARY

While only 2 of the 20 fatal accidents of table 3 were discussed in detail, the remainder have similar histories. Blessed with hindsight, these evaluations can be readily made; but consideration has to be given to the plight of the men who must develop these bump-prone seams. It is difficult at best, when working in that environment, to ascertain conditions on a continuous basis. However, in the light of present knowledge, the following suggestions are made:

1. In pillaring operations as much coal as possible should be recovered. Leaving pillar remnants or whole pillars in the gob should be avoided.

2. Pillar line points should be avoided insofar as possible. While all points cannot be eliminated, the number can be reduced by careful planning. Long entries protected by barrier pillars 200 to 500 feet wide on each side should be avoided.

3. Roof spans projecting over the gob should be kept as short as possible. Often orientation of the pillar line can be selected so that it parallels the direction in which the roof breaks most readily.

4. Development work should not be done in pillar line abutment areas. Blocking out pillars should be planned so that such work is not less than three or four pillars ahead of the pillar line. In any event, development places should not be advanced toward the pillar line in an abutment zone because of the probability of encountering a high-stress area.

5. Significant reduction in the size of a pillar should be done as quickly as possible before overburden pressures have time to readjust and load the pillars.

6. Pillars should all be approximately the same size and shape, preferably square and large enough to insure adequate support of the overburden.

7. Consideration should be given to the use of such monitoring techniques as pressure cells, convergence measurements, delineating lithological transitions, and geophysical methods to detect pending problems.

8. Prevention techniques other than mine design that should be considered include slotting, drilling, volley firing, and water infusion. Each of these methods is a means of destressing coal and must be used with extreme caution.

9. Oversimplification of bump causes and effects should be avoided. More geological rock mechanics data are necessary to increase understanding and to develop better methods of ground control.

BIBLIOGRAPHY

1. Holland, T., and E. Thomas, Coal Mine Bumps: Some Aspects of Occurrence, Cause and Control, BuMines 535, 1954, 37 pp.

2. Holland, T. Cause and Occurrence of Coal Mine Bumps, Min. Eng., v. 10, No. 9, Sept. 1958, pp. 994-1004.

3. Adler, L., and M-C. Sun, Ground Control in Bedded Formations, Research Division, VPI, Bull. 28, 1968, 268 pp.

4. Kauffman, P. W., S. A. Hawkins, and R. R. Thompson, Room and Pillar Retreat Mining: A Manual for the Coal Industry. BuMines IC 8849, 1981, 228 pp.

PROCEEDINGS
OF THE
FIFTEENTH ANNUAL INSTITUTE ON COAL MINING HEALTH, SAFETY AND RESEARCH

BLACKSBURG, VIRGINIA
AUGUST 28-30, 1984

SPONSORING ORGANIZATIONS:

DEPARTMENT OF MINING & MINERALS ENGINEERING
VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY

MINE SAFETY AND HEALTH ADMINISTRATION
U.S. DEPARTMENT OF LABOR

BUREAU OF MINES
U.S. DEPARTMENT OF THE INTERIOR

EDITED BY:

Michael Karmis
Department of Mining and
Minerals Engineering
Virginia Polytechnic Institute
and State University

William H. Sutherland
Mine Safety and Health
Administration
U.S. Department of Labor

David R. Forshey
Bureau of Mines
U.S. Department of the Interior

J. Richard Lucas
Department of Mining and
Minerals Engineering
Virginia Polytechnic Institute
and State University

Gavin J. Faulkner
Department of Mining and
Minerals Engineering
Virginia Polytechnic Institute
and State University

Published by the Department of Mining and Minerals Engineering
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061