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Occurrence, predication, and control of coal burst events in the U.S.

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ABSTRACT

Coal burst represented a major hazard for some U.S. mining operations. This paper provides an historical review of the coal burst hazards, identifies the fundamental geological factors associated with these events, and discusses mechanisms that can be used to avoid their occurrences. Coal burst are not common in most underground mines. Their occurrence almost always has such dramatic consequences to a mining operation that changes in practice are required. Fundamental factors influencing coal burst events include strong strata, abnormal strata caving, elevated stresses, critical size pillars and the lack of sufficiently sized barrier pillars during extraction. These factors interact to produce excessive stress, seismic shock and loss of confinement mechanisms. Over the 90 years of dealing with these hazards, many novel prevention controls have been developed including novel mine designs and extraction sequences, most of which are site specific in their application. Without an accurate assessment of the fundamental factors that influence coal burst and knowledge of their mechanisms of occurrence, control techniques may be misapplied and risk inadequately mitigated.

1. Introduction

Coal burst (here using “coal burst” to avoid showing a preference for the eastern designation of coal bump or the western usage of coal bounce) are violent failures of ribs, roof or floor in underground mines. They are known to occur in complex ways and often under unique sets of conditions. This has made them extremely difficult to anticipate and control. Assessing coal burst risk requires engineers, managers, and safety professionals to recognize the fundamental factors responsible for these events. This helps practitioners recognize the hazard potential and understand the context in which various controls and barriers should be used. Only then can coal burst events be anticipated and appropriate mitigation techniques deployed.

Over the last 90 years, a few coal burst events have been anticipated but most have eluded prediction. The authors examined the historical records and determined that an inadequate understanding of the initiating geologic factors and their associated mechanisms of occurrence have contributed to the poor predictive capability. The historic records also indicated that control techniques have typically been site specific in their application.

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2. Coal burst trends

The first major survey of coal bursts events were made by Holland and Thomas [1]. They examined 177 instances of coal bursts occurring from 1925 to 1950 and recommended specific mining practices that are still important today. In 1984, Goode et al. analyzed the records of burst events from 1950 until 1984, and found that 28 fatalities had occurred since the Holland and Thomas report, 14 in the eastern U.S. and 14 in the western U.S. Fig. 1 depicts the coal basins where bursts have been most prevalent. They concluded that many improvements had occurred as a result of the extensive use of continuous mining machines, but also noted that many of the same unfavorable mining conditions and practices discussed by Holland and Thomas still existed [1]. For example, the mobility and versatility of the continuous miner led to the development of novel pillar splitting and extraction sequencing designs for bursts control. Ten years after conclusions by Goode et al., the U.S. Bureau of Mines reported on a coal burst database that included more than 170 events [2,3]. The database was constructed from U.S. Bureau of Mines and Mine Safety and Health Administration (MSHA) accident and incident reports written between October 12, 1936 and January 21, 1993. A total of 87 fatalities and 163 injuries were identified. The 1980s witnessed the greatest outbreak of bursts, accounting for 27% or 31% of the total fatalities, while the second largest percentage of fatalities occurred during the 1950s (23%). West Virginia recorded the greatest

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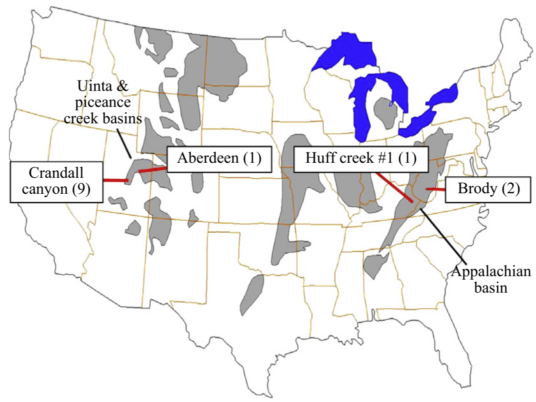

Fig. 1. Coal basins where bursts have been most prevalent.

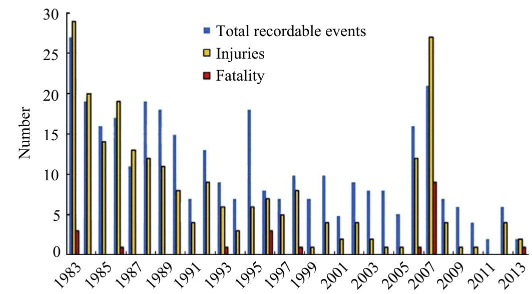

Fig. 2. Coal bursts events, injuries and fatality trends from 1983 to 2013.

Table 1
Number and percentage of coal bursts by state, 1983–2013.

State	Mine with burst		Burst event	
	Number	Percentage	Number	Percentage
Alabama	1	1.3	1	0.3
Colorado	14	18.2	77	22.9
Kentucky	15	19.5	32	9.5
Utah	30	39.0	194	57.6
Virginia	6	7.8	13	3.9
West Virginia	11	14.3	20	5.9
Total	77	100	337	100

number of documented bursts (53), followed by Virginia (40), Colorado (30), Utah (26) and Kentucky (19). Alabama and Washington each had one reported burst event.

As noted in Fig. 1, Appalachian (especially the central portion) and the Uinta-Piceance Creek Basins have historically the highest concentration of coal bursts, and Fig. 1 also shows the locations (mine name and the number of fatalities) of the most recent coal bursts fatalities (since 2000).

Coal bursts trends were analyzed by the authors using the MSHA Data Retrieval System. The narratives of the Data Retrieval System were searched for terms such as bursts, outburst, bumps, bounces, thumps and pushes. Each of the entries was examined and verified the coal bursts classification. Between 1983 and 2013, 337 coal bursts events occurred in 77 mines located within six states (Table 1). During this period, Utah had by far the most events (57.6%). Of the 337 events, 140 (41.5%) were reported to MSHA without associated injuries. Typically, a coal burst event requires MSHA notification when miners are withdrawn from the section or mining activity is disrupted for more than one hour. It is assumed that this subset of the data base represents coal bursts of significant magnitude. Undoubtedly, there have been many more coal bursts that did not require MSHA notification.

Coal burst are a significant mining problem because they can result in serious injury to miners. The MSHA data showed that the 337 events produced 240 injuries, 20 of which were fatalities. It should be noted that two additional fatalities occurred in 2014 at the Brody Mine in West Virginia. Fig. 2 shows the annual number of coal bursts injuries and fatalities from 1983 until 2013. For the 23 years of data, there is a general downward trend to the number of injuries. However, in 2006 and 2007, the number of injuries increased significantly. The 2007 injuries reflect the Crandall Canyon disaster where 9 miners were fatally injured and six others seriously injured during two coal bursts events. From 2008 to 2013, the number of events and associated injures has dropped significantly.

The data demonstrate that coal burst still represent a significant safety problem for underground mines and their workers. Management of bursts risk, covered in another report by Iannacchione and Tadolini, can be accomplished through (1) administrative controls that removed the miner from the hazardous environment, (2) personal protective equipment to protect against out-bursting material, (3) barriers to shield the miners, i.e. steel flippers and rubber belting deployed from the tips of shield canopies, etc., (4) engineered prevention controls, i.e. mine layouts that mitigate hazardous conditions, (5) engineered remediation controls, i.e. distress drilling, volley firing, water injections, etc., and (6) avoidance of bursts-prone areas [4].

3. Fundamental factors

A proper assessment and management of a coal mine burst hazard must rely on an understanding of the fundamental factors responsible for their occurrence. While a complete inventory of these factors is beyond the scope of this paper, some of the more important factors are discussed. Fundamental factors include overburden and abutment stresses, pillar/barrier shapes and size, strata's caving characteristics, and stiffness of the strata surrounding the coalbed.

3.1. Vertical stresses

The first fundamental factor stress is in some ways, the fuel that drives the process. Stress, both static and dynamic, can strain rocks to failure. Increasing overburden produces higher levels of vertical stress. Many authors have associated overburdens greater than 300 m with increased coal burst occurrence. These stresses increase as support is removed from the existing mine pillar support structure, first during development mining and later in conjunction with full or partial extraction mining. Coal burst on development generally increases in potential when the overburden is greater than 500 m. However, when overlapping conditions, such as multiple seam mining or geologic discontinuities, are encountered, coal burst can occur at lesser depths. In all of these cases, violent failure occurs when the levels of stress are elevated.

3.2. Lack of sufficiently sized barrier pillars during full extraction mining

A second fundamental factor is barrier pillar design. Most full extraction mining requires adequately designed barrier pillars. There are many techniques available to assist in this effort and it is beyond the scope of this paper to fully define this process. For example, Ashley proposed an equation for sizing barrier pillars based on the thickness of the coalbed and overburden [5]. Later, Campoli et al. introduced a design protocol for retreat mining in barrier pillars [6]. This design protocol demonstrated the need