CHAPTER 23

Ground Control Issues for Safety Professionals

Christopher Mark, Ph.D.
Rock Mechanics Section Chief

Anthony T. Iannacchione, Ph.D.
Deputy Director
National Institute for Occupational Safety and Health (NIOSH), Pittsburgh, Pennsylvania

INTRODUCTION

Falls of ground continue to be one of the most serious causes of injury to U.S. miners. Of the 256 fatal injuries that occurred in mining between 1996 and 1998, 59 (23%) were caused by falls of ground (Table 23.1). Falls of ground affect some sectors of the mining industry more severely than others. For instance, nearly 40% of the 98 coal mine fatalities between 1996 and 1998 were caused by falls of ground. Underground miners are at much greater risk than surface miners. Nearly half (45 out of 101) of underground mine fatalities were attributed to roof, rib, and face falls, while only 6% of the 155 surface fatalities were caused by falls of highwalls or slopes.

The goal of this chapter is to provide guidance to safety professionals tasked with preventing ground fall injuries. This chapter combines an analysis of the Mine Safety and Health Administration's (MSHA) accident and injury data with a survey of industry "best practices" to safeguard miners from ground falls. Ultimately, this approach can help to form the basis of a sound, proactive ground control program for the mining industry.

SOURCES OF DATA

All the injury data examined in this study were derived from MSHA's fatal investigation reports and the MSHA accident database. Because falls of ground often result in serious injury, MSHA "Fatalgrams" and fatal investigation reports provide a useful snapshot of ground control issues in the mining industry. These reports are available to the public (on the MSHA Web site at www.msha.gov). Fatalgrams are one-page summaries that are usually published within a month of an accident. They contain very basic information about the accident with a graphic and a short section on relevant best practices. Fatal investigation reports are the official accident investigation reports filed by MSHA personnel. These reports contain general information about the mine, a description of the accident, physical factors involved in the accident, a conclusion, and enforcement actions. Enforcement actions typically identify citations and discuss violations to the Federal Mining Law.

MSHA also maintains comprehensive statistical data on the mining industry's accident and injury record. The law requires that mines file a report on every reportable accident that occurs, containing information on the accident's location, severity, classification, activity, and nature of injury. A short narrative is generally included as well. Accident reports can be searched by many of the above fields.

TABLE 23.1 Fatalities from 1996 to 1998 by commodity for both falls of ground and other mining classifications

	1996		1997		1998		Total	
	Underground	Surface and Prep Plants	Underground	Surface and Prep Plants	Underground	Surface and Prep Plants	Underground	Surface and Prep Plants
Coal falls of ground	13	1	9	0	14	1	36	2
Coal total	**33**	**6**	**22**	**8**	**22**	**7**	**77**	**21**
Metal falls of ground	1	0	2	1	3	0	6	8
Metal total	**5**	**3**	**7**	**5**	**5**	**5**	**17**	**13**
Nonmetal falls of ground	0	0	0	0	0	0	0	0
Nonmetal total	**0**	**1**	**1**	**2**	**2**	**4**	**3**	**7**
Stone falls of ground	2	2	1	1	0	1	3	4
Stone total	**2**	**25**	**2**	**26**	**0**	**23**	**4**	**74**
Sand/gravel falls of ground	0	0	0	0	0	0	0	0
Sand/gravel total	**0**	**11**	**0**	**17**	**0**	**12**	**0**	**40**
Total falls of ground	**16**	**3**	**12**	**2**	**17**	**2**	**45**	**7**
Total mining	**40**	**46**	**32**	**58**	**29**	**51**	**101**	**155**

From 1996 to 1998, U.S. miners suffered a total of 55,096 injuries, which ranged in severity from death (degree 1) to injuries with no days away from work or restricted duty (degree 6). Six percent of the total injuries were from falls of ground, including machine accidents where caving rock was coded as the source. As the data in Table 23.2 indicate, 98% of all nonfatal fall of ground injuries occurred in underground mines, with underground coal mines accounting for 83% of the total.

Table 23.2 also shows the distribution nonfatal fall of ground injuries by severity and commodity. The injuries are classified into lost time injuries that resulted in permanent disability (degree 2) or days off work (degrees 3–4), and injuries without lost time that resulted in no more than restricted duty (degree 5–6). Overall, groundfall injuries appear to be more serious than other types of mining injuries. Sixty-five percent of all ground fall injuries resulted in lost time, compared to 54% of all types of mining injuries.

Analysis of the accident database allows safety professionals to learn from the experience of the entire industry. The factors responsible for many ground fall injuries emerge from this analysis, and possible solutions can be identified as well. It also allows for the timely recognition of trends, both from a standpoint of identifying successful interventions as well as focusing on emerging issues.

LEGAL FRAMEWORK

Laws governing mining in the United States are listed in the *Code of Federal Regulations* (CFR) under Title 30—Mineral Resources. Laws pertaining to the control of ground in surface and underground mines are covered in four parts, characterized by surface coal mining (Part 77), underground coal mining (Part 75), metal/nonmetal surface mining (Part 56), and metal/nonmetal underground mining (Part 57). The U.S. Mining Law contains both specific and sweeping statements, and its generalized

TABLE 23.2 Nonfatal fall of ground injuries from 1996 to 1998

Severity	Commodity	Underground	All Other	Total
Lost time injuries (degree 2 to 4)	Coal	1807	23	1830
	Metal	140	5	145
	Nonmetal	15	0	15
	Stone	14	9	23
	Subtotal	**1976**	**37**	**2013**
Injuries without lost time (degrees 5 and 6)	Coal	777	9	786
	Metal	269	3	272
	Nonmetal	23	1	24
	Stone	16	7	23
	Subtotal	**1085**	**20**	**1105**
All nonfatal injuries	Coal	2584	32	2616
	Metal	409	8	417
	Nonmetal	38	1	39
	Stone	30	16	46
	Total	**3061**	**57**	**3118**

TABLE 23.3 Violations of Part 75 from fall of ground fatal investigation reports. 1996–1998

Subsection Violated	Title	Number
75.202	Protection from falls of roof, face, and ribs	18
75.203	Mining method	1
75.204	Roof bolting	0
75.205	Installation of roof support using mining machine with integral bolter	0
75.206	Conventional roof support	0
75.207	Pillar recovery	0
75.208	Warning devices	0
75.209	Automated temporary roof support systems	1
75.210	Manual installation of temporary support	0
75.211	Roof testing and scaling	0
75.212	Rehabilitation of areas with unsupported roof	1
75.213	Roof support removal	3
75.214	Supplemental support materials, equipment, and tools	0
75.215	Longwall mining systems	0
75.220	Roof control plan	6
75.221	Roof control plan information	0
75.222	Roof control plan—approval criteria	0
75.223	Evaluation and revision of roof control plan	0

language promotes flexibility and innovation. For example, in coal mining, each mine is required to submit its own roof control plan, which contains, in many cases, many details as to how the mine will comply with ground control aspects of the law.

Underground coal mining roof control is covered in 18 subsections within Part 75. Although each of these sections outlines an important step in controlling falls of ground, some sections are cited more frequently in fatal investigation reports. Between 1996 and 1998, a total of 30 citations were given to mines following fatal accidents, citing 6 of the 18 sections (Table 23.3). The most frequently cited subsection was 75.202–protection from falls of roof, face, and rib. Section 75.202 requires that ground support must protect persons from hazards related to falls of the roof, face, or ribs and coal or rock bursts in areas where they work or travel. It also states that no person may work or travel under an unsupported roof unless in accordance with special procedures. Another common citation listed was violation of the roof control plan. The language also states that additional measures shall be taken to protect persons if unusual hazards are encountered.

Underground metal/nonmetal mining roof control is covered in nine subsections within Part 57. Between 1996 and 1998, the most frequently cited subsection following fatalities was 57.3200, which requires that hazardous ground conditions be taken down or supported before other work or travel is permitted (Table 23.4). The law also requires that the affected area be posted with a warning against entry and, when left unattended, that a barrier be installed to impede unauthorized entry. Many of the fatal investigation reports reveal that geologic structures contributed to the conditions referred to in subsection language. In four of the reports, inadequate examination of ground conditions was cited.

Surface mining ground control is covered in 9 subsections within Part 56 for metal/nonmetal mines and 15 subsections within Part 77 for coal mines. Several violations cited subsection 56.3200, which requires hazardous ground conditions to be taken down or supported before work or travel is permitted. The directive states that until corrective work is completed, the area shall be posted with a warning against entry and, when left unattended, a barrier shall be installed to impede unauthorized entry.

ROOF CONTROL PLANS

Each coal mine operator is expected to develop and follow a roof control plan, approved by the MSHA district manager, that is suitable to the prevailing geological conditions and the mining system to be used at the mine. The law also outlines what should be contained within the plan (75.221), how the plan will be approved (75.222), and how revisions to the plan will be evaluated (75.223). The data discussed above suggest that violations to the plan can result in serious injury to the miner. Management *must* communicate and enforce the specifics of the roof control plan to the workforce. Additionally, the plan cannot be viewed as a static document. As conditions of mining change, the plan must be updated and resubmitted to the local MSHA district manager for approval. Safety professionals may have no greater tool at their disposal for addressing ground control issues than the roof control plan.

The mine operator is also responsible for taking any necessary measures to protect persons if unusual hazards are encountered. When new support materials, devices, or systems are used as the only means of roof support, the MSHA district manager may require that their effectiveness be demonstrated by experimental installations as part of a test plan.

Roof control plan implementation begins by instructing all persons who are affected by its provisions. The approved plan and any revisions must be available to the miners and their representatives and must be posted on a mine bulletin board.

Subsection 75.221 lists the information that must be included in the roof control plan. Some of the most important issues include:

- Specifications of all supports that may be used, including the length, diameter, grade, type of anchorage, drill hole size, and bolt torque or tension ranges for roof bolts
- Installation procedures for supports, including spacing and sequence of roof bolts
- Maximum automated temporary roof support (ATRS) distance beyond the last row of permanent support
- Entry width, size of pillars, method of pillar recovery, and the sequence of mining pillars
- Frequency of test holes to be drilled at least 12 in. above the roof bolt anchorage horizon
- Special support and mining systems, such as for mine entries within 45 m (150 ft) of an outcrop.

The roof control plan sets forth minimum requirements, specifically in areas such as bolt length and bolt spacing. Additional support measures must be used to adequately support local adverse conditions. When conditions indicate that the plan is not suitable for controlling falls of ground, the operator must propose revisions of the roof control plan (Sec. 75.223). Conversely, when the accident and injury experience at the mine indicates the plan is inadequate, MSHA will generally require changes to the plan. MSHA reviews the roof control plan at each mine every six months. To assist with the review, all unplanned roof falls, rib falls, and coal or rock bursts that occur in the active workings must be plotted on a mine map.

TABLE 23.4 Violations from Part 57 from fall of ground fatal investigation reports, 1996–1998

Subsection Violated	Title	Number
57.3200	Correction of hazardous conditions	6
57.3201	Location for performing scaling	1
57.3202	Scaling tools	1
57.3203	Rock fixtures	0
57.3360	Ground support use	0
57.3400	Secondary breakage	0
57.3401	Examination of ground conditions	4
57.3460	Maintenance between machinery or equipment and ribs	0
57.3461	Rock bursts	0

GROUNDFALL HAZARDS AND BEST PRACTICES TO CONTROL THEM

The 51 fatal investigation reports from 1996 to 1998 provide a window on the most significant groundfall hazards facing today's miners. Some of these hazards, such as geologic features, affect all miners to one degree or another. Others are specific to the commodity or mining method. Many are the subject of recent or ongoing NIOSH research and are addressed in papers available at www.cdc.gov/niosh/pit. Best practices can also be obtained from MSHA literature, including the "cards" available at www.msha.gov/s&hinfo/prop/prophome.htm.

Geologic Discontinuities

Mines are unique structures because they are not constructed of manmade materials, such as steel or concrete, but are built of rock, just as nature made them. Thus, integrity of a mine structure is greatly affected by the natural weaknesses or discontinuities that disrupt the continuity of the roof and rib. Geologic discontinuities can originate while the material is being deposited by sedimentary or intrusive processes, or later when it is being subjected to tectonic forces. Depositional discontinuities include slips, clastic dikes, fossil remains, bedding planes, and transition zones. Structural discontinuities include faults, joints, and igneous dikes. Some of the most important discontinuities that affect mine safety are described below.

- *Slips* are breaks or cracks in the roof, and they are the features most often cited in underground coal mine fatality reports. When slips are more than several feet long and are steeply dipping, they form a ready-made failure surface. Their surfaces are usually *slickensided*–i.e., smooth, highly polished, and striated. Two slips that intersect form an unsupported wedge that is commonly called a *horseback*. Undetected slips that do not fail during development have a tendency to pop out when subjected to abutment pressures generated during pillar recovery operations. Longer or angled bolts may be used to support slips, and straps or truss bolts can be even more effective.
- *Joints* are fractures commonly found in hard rocks. They occur in sets with similar orientation. Often several sets of joints occur at angles to each other, creating unstable blocks that must be supported by roof bolts.
- *Fossil remains* are the remnants of plants and animals that lived during the time when the sediments that later became rocks were being deposited. For example, kettlebottoms are fossil trees that grew in ancient peat swamps (Figure 23.1). They occur in every U.S. coal basin, but are especially abundant in southern West Virginia and eastern Kentucky. Dinosaur footprints are another fossil remain found in the roof rocks of coal mines in Utah, Wyoming, and Colorado. Fossil remains can fall without warning and should always be carefully supported (Chase 1992). Roof boltholes should never be drilled directly in fossil remains, because the vibrations could cause them to be dislodged.
- *Bedding planes* are typically found in sedimentary rocks and can extend great lateral distances. Bedding planes represent sharp changes in deposition (e.g., limestone to clay, or sandstone to coal). These planes can separate readily and are frequently involved in roof falls.

FIGURE 23.1 Large kettle bottom in an underground coal mine (photo by F. Chase)

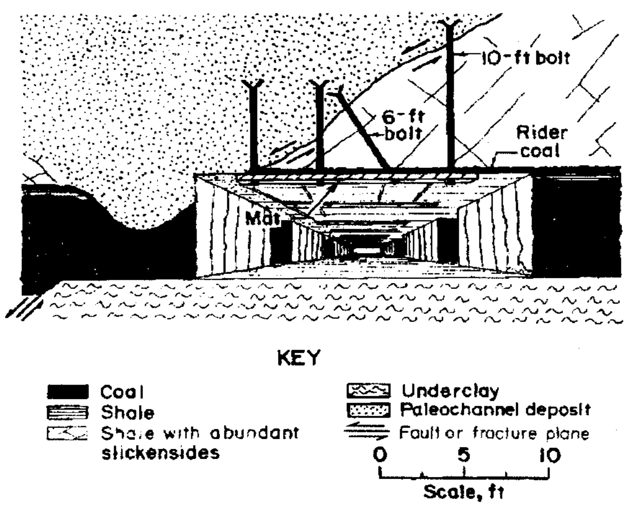

FIGURE 23.2 Suggested roof support for a stream channel transition zone (Chase 1992)

- *Transition zones* occur in many types of strata but are particularly common in sedimentary rocks. A transition zone occurs when some change in deposition causes a change in sedimentation. Different types of sediments compact at different rates. Discontinuities are abundant in the transition zones between distinct strata. For example, where ancient streambeds eroded the adjacent sediments, remnants of the stream channel disrupt the continuity of the normal roof beds, resulting in large slip planes (Figure 23.2).
- *Faults* are structural displacements within the rock. Tectonic forces can cause rocks to break and slip. Faults often contain weak *gouge* material, and the country rock around them can be distorted, fractured, and hazardous (Figure 23.3). Faults are often cited as contributing to surface mine highwall failures.

Discontinuities occur in many shapes and sizes and are generally difficult to recognize in advance of mining. They often contribute to fatal accidents, frequently in combination with other factors. Miners, and particularly roof bolt operators and face drillers, need to be trained to recognize geologic discontinuities as soon as they are exposed by mining. They must also be aware of the proper support techniques and have the necessary support materials available.

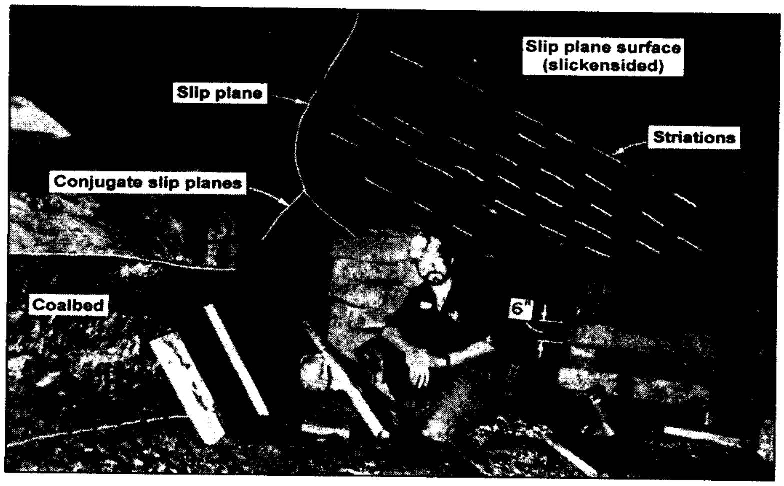

FIGURE 23.3 Fault in an underground coal mine (photo by G. Molinda)

TABLE 23.5 Factors in underground coal mine fall of ground fatalities

Factor	1996	1997	1998	Total
Pillar extraction	4	4	5	13
Inby roof support	4	0	5	9
Intersections	1	3	2	6
Geology	1	4	1	6
Rib	2	3	0	5
Construction	1	0	3	4
Skin control	1	0	2	3
Longwall face	1	1	0	2

Underground Coal Mine Hazards

Between 1996 and 1998, 36 underground coal miners were killed in 33 separate incidents. Table 23.5 lists the hazards that contributed to these incidents and their frequency. In some cases, more than one hazard was involved. For example, 13 fatalities occurred during pillar extraction, with 3 of the accidents resulting from premature intersection collapses.

Unsupported Roof

Roof bolts and the ATRS are the first lines of defense against roof falls in underground coal mines. When miners go under unsupported roof, they are completely unprotected. Between 1996 and 1998, approximately 25% of coal mine roof and rib fatalities occurred when miners were beyond roof supports. While there are no grounds for complacency, the recent record does represent an improvement from a decade ago, when nearly 50% of ground fall fatalities occurred beneath unsupported roof (Peters 1992). The improvement was achieved through new equipment, enforcement and a persistent educational campaign.

By definition, roof support activities take place very close to unsupported roof. Therefore it is not surprising that most of the fatal accidents involved roof bolt operators or other miners engaged in roof support. Based on the accident record, single-head roof bolt machines appear to be a risk factor. Roof control plans carefully specify the sequence of bolt installation with single-head machines to avoid placing the operator inby support. If these guidelines are not followed, the roof bolt operator can be at risk.

During the early 1990s, the U.S. Bureau of Mines (USBM) conducted an extensive series of interviews with miners to determine why they might go out under unsupported roof (Peters 1992). The most common response was that they had unintentionally walked out beyond the supports. The most effective countermeasure, then, is to ensure that all areas of unsupported roof are clearly posted with highly visible warning devices. Other activities that were associated with going inby supports included:

- Operating a continuous miner or scoop
- Hanging or extending ventilation tube or curtain
- Retrieving items left lying on the ground
- Repairing or restoring power to a continuous miner
- Marking the roof for bolt installation.

Relatively simple procedures or technologies can be implemented to reduce the temptation for workers to intentionally go beyond support. However, training is essential. Mallett and colleagues (1992) argue that verbal admonitions and threats of discipline are less effective than training that graphically imparts the severe consequences of roof falls. A series of three videos was prepared that shows actual miners being interviewed about roof fall accidents that they experienced. The videos also emphasize the impact that roof fall accidents have on people other than the one caught in the fall. These highly effective videos, together with training manuals, are available from the MSHA Academy in Beckley.

Finally, the prevalence of dangerous behavior depends greatly on the miner's perception of the company's policy concerning going under unsupported roof, on how that policy is enforced, and on the attitude and behavior of his supervisor and coworkers. The best prevention programs involve high-level managers who directly communicate their commitment to the goal of keeping people away from unsupported roof.

Roof Bolter Safety

Roof bolt operators are on the front line in the fight against ground falls. They are continually exposed to roof and rib hazards, and historically they have experienced more groundfall-related injuries than any other occupation in mining. Although large roof and rib falls have been responsible for several fatalities, most injuries are caused by relatively small pieces of rock.

A detailed study of the hazards associated with roof bolting was conducted in West Virginia (Klishis et al. 1992; Grayson et al. 1992). The average time for bolting a place was 26.9 minutes, and that time was spent engaged in four primary activities:

- General face preparation
- Tramming, positioning, and setting ATRS
- Drilling holes
- Installing bolts.

The most hazardous face preparation activity was scaling and barring roof. Thick coal seams where the roof is high posed particular hazards. Having a long scaling bar available was essential.

The most severe injuries (with an average of 45 days lost) were associated with setting the ATRS. Pressurizing the ATRS against the top can disturb the roof, and large pieces may rotate and actually fall underneath the support. It is particularly important, then, that other miners stand back while the ATRS is being set.

The greatest number of injuries occurred during the drilling process, which also involved the greatest amount of the total cycle time. Drilling also disturbs the rock, causing pieces to fall. Analysis of the injury data found that operators placed themselves at risk whenever a part of the body left the protective coverage of the canopy. Placing hands around the drill steel or across the drill head also resulted in a number of injuries.

Bolt installation required only 17% of the cycle time but was associated with 25% of the injuries. Miners sometimes went out from under the canopy during installation, particularly in high top. Accidents appeared to be more frequent during the installation of the last row of bolts in a place, because of face falls and a tendency to overextend the ATRS.

The roof bolt machine, with its ATRS and canopy, is the critical piece of safety equipment. It should always be in proper operating condition before it is used. The proper bolting sequence, as defined in the roof control plan, must always be followed. Several fatalities have resulted when operators of single-boom machines installed bolts out of sequence and placed themselves under unsupported roof.

Rehabilitation of roof falls and construction of overcasts and boom holes present special hazards. In many such areas the roof is unusually high, and often the ATRS cannot effectively contact it. If the ATRS cannot be set against the top, it is necessary to set jacks for temporary support or use a manufacturer's approved ATRS extension. Two roof bolt operators have been killed in recent years while bolting high top during mine construction activities.

Roof bolt operators are also responsible for protecting the entire crew with high-quality bolt installations. Poorly installed roof bolts can be worse than none at all, because they provide a false sense of security. Manufacturers' recommendations regarding resin spin and hold times must always be followed. Holes must be drilled to the proper length (not more than one-inch deeper than the bolt's length). The torque on tensioned roof bolts must be checked as required by CFR 75.204(f).

A wide variety of roof bolts are now available, and installation problems may be caused by geologic changes, incorrect practices, or malfunctioning supports. To help identify and resolve problems with roof supports, an extremely valuable *Trouble Shooting Guide* is available (Mazzoni et al. 1996).

If there are any indications of adverse conditions, additional test holes should be drilled and additional support installed. Roof conditions detected during drilling should be communicated to coworkers and management.

Skin Failures of Roof and Rib

Skin failures are those that do not involve failure of the roof support elements, but result from rock spalling from between roof bolts, around ATRS systems, or from ribs. They are of particular concern because they cause injuries and fatalities to workers who should have been protected by supports. In 1997, 98% of the 810 roof and rib injuries suffered by mine workers were attributed to skin failures (Bauer et al. 1999).

Roof skin failures almost always involve pieces of rock that are less than 0.6 m (2 ft) thick. About 40% of the 669 roof skin injuries in 1997 involved roof bolt operators and occurred beneath the ATRS. The other roof skin injuries occurred beneath permanent support and involved workers in a wide variety of activities. Common roof skin control techniques include oversized plates, header boards, wood planks, steel straps, meshing, and (in rare instances) spray coatings (sealants).

Between 1996 and 1998, rib failures resulted in 6 fatalities in underground coal mines. Only one of these fatal injuries was to a face worker, the other five were all mechanics and electricians performing their duties well outby the face. Nearly 80% of the 128 rib injuries that occurred in 1997 took place beneath permanently supported roof. Nonfatal rib injuries resulted in an average of 43 lost workdays each, versus 25 days for the average roof skin injury.

The seam height is the single greatest factor contributing to rib failures (Figure 23.4). The seam height was greater than 2.5 m (8 ft) in all six of the fatalities and was greater than 3 m (10 ft) in three of them. The incidence of rib injuries increases dramatically once the seam height reaches 2.2 m (7 ft). Interestingly, mines with the very thickest seams see lower rib injury rates, probably because

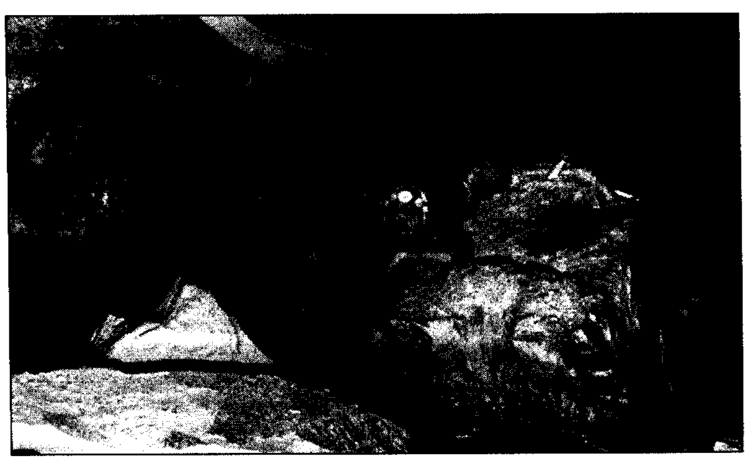

FIGURE 23.4 Large rib failure in a thick coal mine seam (photo by Chase)

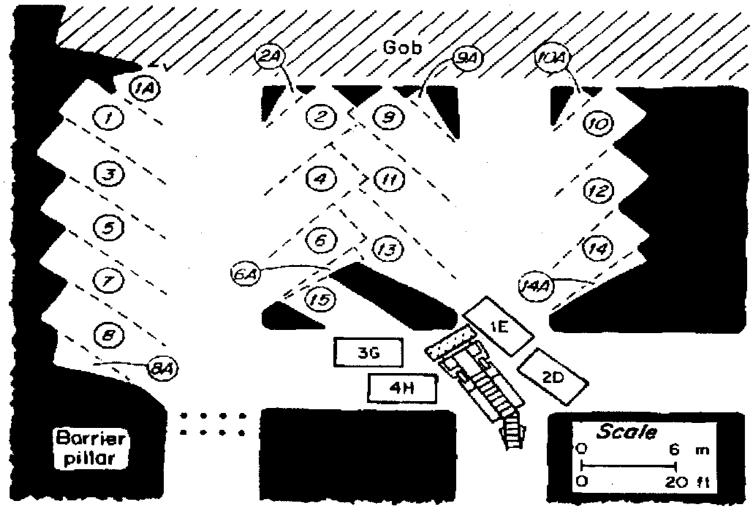

FIGURE 23.5 Christmas tree pillaring plan (Chase et al. 1997)

most of them routinely use rib support. No rib support was used in any of the six fatal accidents, however. Rib failure is often associated with rock partings and/or discontinuities within the pillar, or with overhanging brows created by roof drawrock. The most effective rib supports employ full planks or mesh held in place by roof bolts.

Pillar Recovery

Pillar recovery has always been an integral part of U.S. underground coal mining. It can be a less capital-intensive, more flexible alternative to longwall mining for small, irregular reserves. A recent study estimated that pillar recovery accounts for about 10% of the coal mined underground (Mark et al. 1997).

The process of pillar recovery removes the main support for the overburden and allows the ground to cave. As a result, the pillar line is an extremely dynamic and highly stressed environment. Safety depends on controlling the caving through proper extraction sequencing and roof support. Historically, retreat mining has accounted for a disproportionate number of roof fall fatalities, including 13 between 1996 and 1998. Three of the accidents during this period resulted in double fatalities.

A wide variety of pillar recovery techniques are used. "Partial pillaring" methods include pillar splitting, split-and-tee, three-cuts, and many others. These plans leave a substantial amount of coal in the remnant fenders and therefore postpone the caving action of the roof. When "full pillaring" is practiced, roof caving normally occurs soon after mining is completed. Popular full-pillaring techniques include the outside lift and the Christmas tree (Figure 23.5).

Today, most pillar recovery plans employ 9 to 12 m (30 to 40 ft) extended cuts. The pillars are usually sized so that no roof bolting is required during second mining. One apparent consequence is that because roof bolting accidents are eliminated, nonfatal roof/rib accident rates at pillar recovery mines are actually lower than at other room-and-pillar mines (Mark et al. 1997).

Traditional roof control plans require that numerous timber posts be set during each stage of pillar recovery (Figure 23.6). Recently, mobile roof supports (MRS) have become available that replace many of the timbers (Figure 23.7). MRS resemble longwall shields mounted on bulldozer tracks. They can have many safety advantages over timbers. In particular, they are more effective as roof supports, they do not require workers to approach the mined-out gob area to set them, and they reduce the potential for materials handling injuries (Chase et al. 1997).

Following the roof control plan is absolutely critical to safe pillar recovery operations. Fatality investigations have frequently found that lifts were too wide, too deep, or out of sequence. The plan may also specify the minimum dimensions of the remnant coal left in place called *stumps* and *fenders*. However, the roof control plan is a minimum plan, and additional supports should be used at any indication of bad roof.