An Overview of Groundfall Injuries and Worker Activity in Underground Stone Mines

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Working underground is one of the most hazardous occupations in the United States. Underground mines have a fatality rate of at least 15 times the overall manufacturing rate for the United States (Figure 1-based on MSHA data, 5-year intervals, 1985-1999). Underground stone mines have a fatality rate that is nearly 20 times the manufacturing national average. Three-quarters of these underground stone fatalities result from falls of ground from the mine roof or rib (Figure 2). Examining only groundfall fatalities in underground stone mines, produces a rate that is 13 times that of the overall manufacturing fatality rate for the United States. These high fatality rates in underground stone mines due to groundfalls are a critical concern.

Production from 108 underground stone mines is estimated to range from 70 to 100 million tons per year accounting for 5% to 10% of the nation's output. Economic growth and highway building in par-

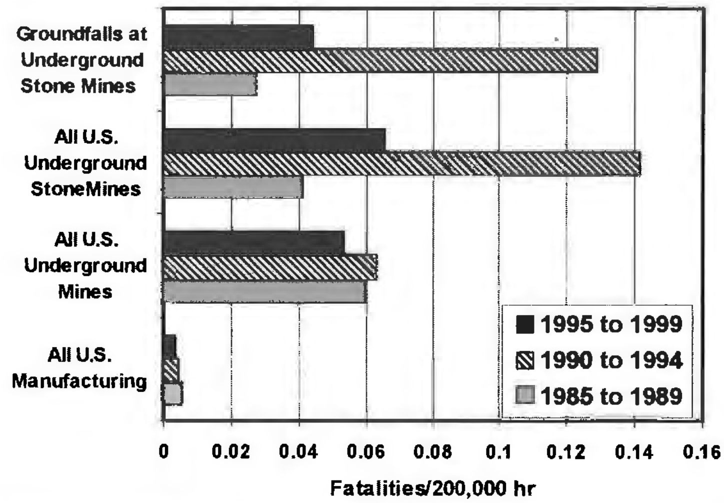

Figure 1 - Comparison of underground mine fatality rates versus U.S. manufacturing fatality rates. (MSHA and DOL)

Figure 2 - Large roof fall at underground limestone mine.

ticular have resulted in record demand for stone in recent years. This high demand, coupled with increasing constraints on surface mining in some areas, has resulted in operators giving greater consideration to developing stone mines underground (Figures 1, 2). An informal NIOSH survey in 1998 identified approximately 17 new underground limestone operations in various stages of planning. Other sources estimate that as many as 35 new underground mines may be in operation by 2005 (Figure 3). Figure 3 indicates the potential growth expected in underground stone mines. In many instances these new mines will employ new or inexperienced workers with minimal knowledge of the potentially hazardous

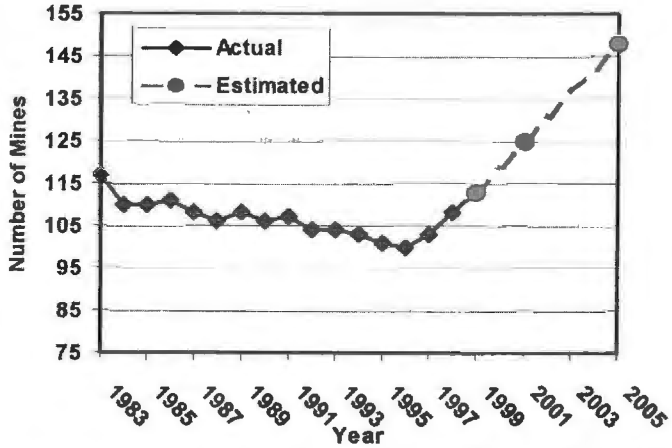

Figure 3 - Potential growth in the number of underground stone mines

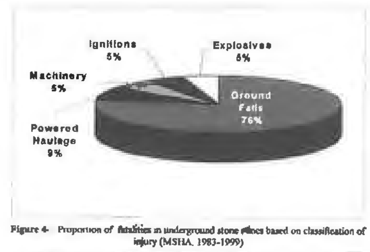

Figure 4 - Proportion of fatalities in underground stone mines based on classification of injury (MSHA, 1983-1999)

underground conditions that exist. With the potential for developing so many new underground stone mines and the already high groundfall fatality rate, NIOSH examined the worker activity at the time of injury to provide information or insight on possible prevention methods.

Methods

Data for this study were obtained from the MSHA accident and employment databases. The study examined the closeout data for the period 1983-1999 for underground stone mines, excluding contractors. Ground control incidents included all roof and rib falls listed in the database, as well as incidents classified as "machinery" where the source of injury was caving rock. The groundfall lost-time injuries were confined to those that resulted in a permanent disability or in actual days away from work (degree of injury 2-4).

The severity of injury was determined by summing the days lost due to nonfatal lost-time groundfalls. Because a single extremely severe injury can dramatically increase the mean number of days lost, the median number of days lost was used for comparing the severity of injuries associated with different worker activities at the time of the groundfall.

Results

Between 1983 and 1999 there were 16 groundfall fatalities representing 76% of all fatalities occurring at underground stone mines (Figure 4). A more even distribution was found with the nonfatal injuries based on injury classification (Figure 5). The highest number of nonfatal injuries was attributed to handling of materials and slips/falls/bumps, both at 22%. Figures 5 and 6 show that groundfalls resulted in 15% of all underground lost-time stone injuries but accounted for 34% of the total days lost which is by far the most of any type of accident. Roof and rib falls cause more than one-third of all days lost and result in more debilitating injuries than any other type of injury classification.

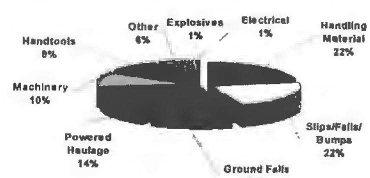

Figure 5 - Proportion of lost-time injuries in underground stone mines based on classification of injury (MSHA, 1983-1999)

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Table 1 - **Number and percent of groundfall injuries, days lost from work days, and median days lost per injury by worker activity, underground limestone mines (MSHA, 1983-1999).**

Worker Activity	Fatal Injuries		Lost-time Injuries[1]		Total days lost		Median number of days lost per incident[2]
	No.	Pct	No.	Pct	No.	Pct	
Scaling	3	19	66	47	7,342	53	16
Handling explosives	3	19	34	24	1674	12	18
Roof bolting	0	0	11	8	853	6	27
Drilling Face	3	19	8	6	3324	24	29
Handling supplies	0	0	7	5	148	1	6
Other	7	43	14	10	485	4	20.5
Total	16	100	140	100	13,826	100	18.5

[1]Groundfall injuries resulting in lost work days (degree of injury 2-4).
[2]The median days lost for all underground stone mine lost-time accidents is 12.

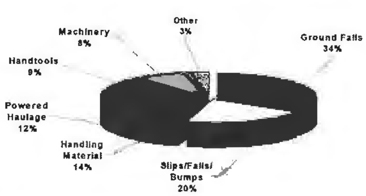

Figure 6 - Proportion of days lost due to lost-time injuries in underground stone mines based on injury classification (MSHA, 1983-1999)

The MSHA accident injury database shows that 156 groundfall related injuries (fatal and lost-time) occurred between 1983-1999. Worker activity at the time of the groundfall accident was reviewed based on the mine worker activity code and accident narrative (Table 1 and Figure 7).

Groundfall injury frequency is associated with these worker activities: 47% during scaling; 24% while handling explosives; 8% during roof bolting, and less than 6% during drilling or handling supplies; and 10% during other activities. There is a slightly different scenario when examining the severity of injury based on the percentage of days lost due to the injury shown in Figure 8. These results show that 53% of the groundfall days lost occur during scaling, 24% during drilling, 12% while handling explosives, 6% during roof bolting, and less than 6% during handling supplies and other activities. A comparison of lost-time ground fall frequency and total days lost (severity) percentages (Table 1 and Figures 7 and 8) show that drilling the face and scaling have a higher severity percentage than the other activities. The significantly higher proportion of days lost for

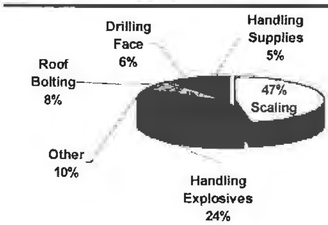

Figure 7 - Proportion of lost-time groundfall injuries based on worker activity (MSHA, 1983-1999)

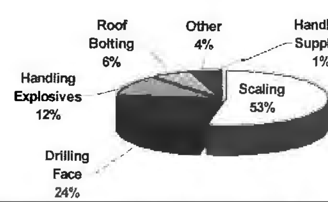

Figure 8 - Proportion of days lost due to lost-time groundfall injuries based on worker activity (MSHA, 1983-1999)

drilling the face and scaling are partly due to two permanent disabilities. These incidents resulted in an extremely high number of statutory days lost being charged to each incident to account for the incapacitating injury and the loss of gainful employment. The effects of these extreme cases on the mean are avoided by using the median to determine the maximum number of days lost per incident for at least 50% of all of the incidents.

To identify practices that may improve safety or protection of miners, the MSHA injury narratives and fatal accident reports were examined in detail for each lost-time and fatal groundfall injury. The results are summarized in the following sections by the type of work the miner was performing at the time of the groundfall injury.

Scaling

Nearly 50% of all groundfall occurrences are related to scaling. The median number of days lost due to scaling accident is 16 days lost per accident which exceeds the overall median of 12 days lost per incident for all underground stone lost-time accidents (Table 1 and Figure 9). Nearly one-third of the 69 scaling accidents are associated with roof or

Firgure 9 - Median days lost for lost-time groundfall incidents in underground stone mines base on worker activity (MSHA, 1983-1999)

rib rock falling onto the basket, scaling machine, or outrigger equipment. This jarring action to the basket or scaling machine often causes the workers to fall from the basket or against the basket rail. According to one accident narrative, two miners were hand scaling the roof from a bucket when a large rock dislodged and struck the corner of the bucket. The weight of the rock on the bucket caused the boom of the scaling rig to bend towards the mine floor until the rock fell to the floor. The boom then catapulted upward, throwing the two scalers from the bucket. In many of these accidents, the failure to use body harnesses resulted in severe injuries. In another narrative an employee was hand scaling while leaning out of a basket when a rock (10 by 7 by 24 ft) fell and struck the outrigger of the scaling machine, causing the machine to fall on its side. The employee was thrown from the basket but a harness, most likely, prevented the worker from being either thrown to the floor or possibly being crushed by the machine. Although his skull was fractured, this incident could have resulted in a fatality if the employee had not been wearing a personal protection harness.

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In some cases, scaling machines and outriggers may need to be better equipped to absorb and deflect these groundfalls. Perhaps the bucket needs to have a canopy or a partial cage and padded to alleviate these types of injuries. It may benefit the workers in the bucket if they wear a hard hat with a chin strap or other type of head protection that could not be easily thrown off during a fall. A previous report suggests the development of personal protection equipment for the scaler to cushion the shock from falling rock which may lessen the severity of scaling injuries.

Another factor examined was the proportion of these accidents associated with hand scaling. Although the narratives are not always specific, it appears that at least 60% of scaling accidents involved hand scaling. Utilizing a machine scaler, where the mine worker is protected by an enclosed cab, would significantly reduce injuries from groundfalls during scaling operations.

Handling explosives

The worker activity of handling explosives is associated with the second highest percentage (24%) of lost-time injuries from groundfalls (Table 1). Based on MSHA reports, 19 of the 34 injuries that occurred while handling explosives were related to the task of loading explosives into the holes. The typical loading injuries result in a median of 16 days lost per incident in comparison to all underground stone mines with a median of 12 days lost per incident. The majority of these incidents result in injury to the victim's back and shoulder.

It appears most of these groundfalls are small-sized rock pieces that fall from the face and roof. Perhaps these incidents could be prevented by wearing some type of protective clothing or gear that would lessen the impact or deflect these small rocks.

Another grouping of handling explosives accidents is associated with groundfalls occurring while the miner is cleaning out bottom holes. Two of these incidents resulted in a fatality, and according to the MSHA fatality report, "the employees routinely cleaned the bottom holes before entering the basket and going up to check the roof. They relied entirely on visual inspection of the roof for ground conditions". The proper procedure is to check and sound the roof and rib before cleaning the bottom holes.

Roof bolting

Roof bolting activities associated with only 8% of the lost-time groundfall injuries and 6% of days lost but produced a very high injury severity–a median of 27 days lost per bolting incident (Table 1 and Figure 9) which is more than double the median rate for all underground stone mine accidents. Miners working from a basket to install the bolts have more injuries than miners using an automated bolter. The bolt operator protected in a cab has less exposure to roof fall hazards than those bolters using a basket to install the roof bolt. Adding a partial cage or canopy to the basket may reduce these types of injuries which are typically severe.

Drilling

Although the activity of drilling the face was associated with only 6% of the lost-time groundfall accidents, these incidents accounted for 24% of the days lost and 19% of the fatal accidents (Table 1). The median days lost per drilling accident is 29 days lost per incident, which equates to nearly a month and a half of recuperation. This is the highest severity of all worker activities and more than double the rate for all underground stone mine accidents (Figure 9). These severe and fatal groundfall injuries that occur during face drilling activities need to be investigated further.

The MSHA fatality investigation reports for all three face drilling fatalities indicate that inadequate examination and testing of the ground conditions prior to work performed in the area were major factors in these incidents (Figures 6, 7).

The report on one accident, which resulted in multiple fatalities, further recommended using a mechanical scaler, reducing mining height, spot bolting, limiting taking floor lifts, and ground control hazard training for all miners (Figure 6).

Although the detail provided in the MSHA nonfatal narratives is limited, the face drilling operation narratives indicate that in at least 75% of these incidents the victim was located outside of the cab. In most instances, the victims were changing drill steel or checking the drill alignment. Perhaps, moving the location of where the drill steel is being changed, away from the drilled face to an area where the rib and roofs are more stable, could alleviate these types of lost-time injuries.

Other

With over 40% of fatal groundfall injuries (Table 1) attributed to other types of miscellaneous worker activities, the MSHA fatality reports were reviewed to find any other associated accident cause.

Although the other worker activities are all different or unrelated to the accident, 4 out of the 7 fatalities occurred while the victims were entering a recently blasted face area. These fatalities resulted from the fall of roof or face due to rock loosened by the recent blast. In two of these cases, MSHA was unable to determine why these victims were in the blast area. Even though these groundfall accidents are attributed to not properly inspecting and scaling the loose rock prior to entering the area, the puzzling question remains: Why did the workers proceed into these very hazardous areas, especially if there was no cause to be there? Possibly, hazard training would be a useful tool to emphasize severe groundfall risk associated with a freshly blasted mine face and the proper procedures for entering the area.

Summary

Groundfall incidents that result in fatalities and lost-time injuries to underground stone mine workers are tragic events. Any action that can prevent or reduce the potential for these devastating occurrences is a positive step towards increased worker safety. This study identified these specific groundfall accident injury trends and some recommended preventive measures:

• Scaling injuries result in highest frequency and number of days lost due to roof falls.

•Scaling injuries often occur from the impact of falling rock onto the basket. It is critical that safety harnesses and other personal protection equipment be correctly utilized during scaling operations.

•Scaling injuries are frequently associated with hand scaling operations. The use of mechanical scalers with protective cabs would reduce the exposure to these types of injuries.

•Roof bolting injuries are often attributed to bolting from a basket. Use extra safety precautions when bolting from a basket, or use mechanical bolters.

•Injuries can be reduced by examining, testing, and scaling the mine roof and rib before drilling and cleaning bottom holes.

•Loading explosives puts the worker at risk of rock falls that may result in

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shoulder and back injuries. Protective clothing or gear could be used that would lessen the impact or deflect these small rock pieces.

•Face drilling accidents result in the highest injury severity in terms of days lost as well as several fatalities. Many of the nonfatal face drilling incidents are associated with the victim being outside of the cab, usually changing drill steel or checking the drill alignment. Perhaps moving the location of where the drill steel is being changed, away from the drilled face to an area where the rib and roof are stable, could reduce some these injuries.

•Other or miscellaneous worker activities included instances in which several victims entered a recently blasted face area and were fatally injured by roof or face falls due to rock loosened by a blast. Hazard training would be a useful tool to emphasize the severe groundfall risk associated with a freshly blasted mine face and the proper procedures for entering the area.

With more than 75% of the underground stone fatalities related to groundfalls (Figure 4), understanding and addressing past roof and rib trends is critical to ensure a safe future for mine workers in the underground stone industry.

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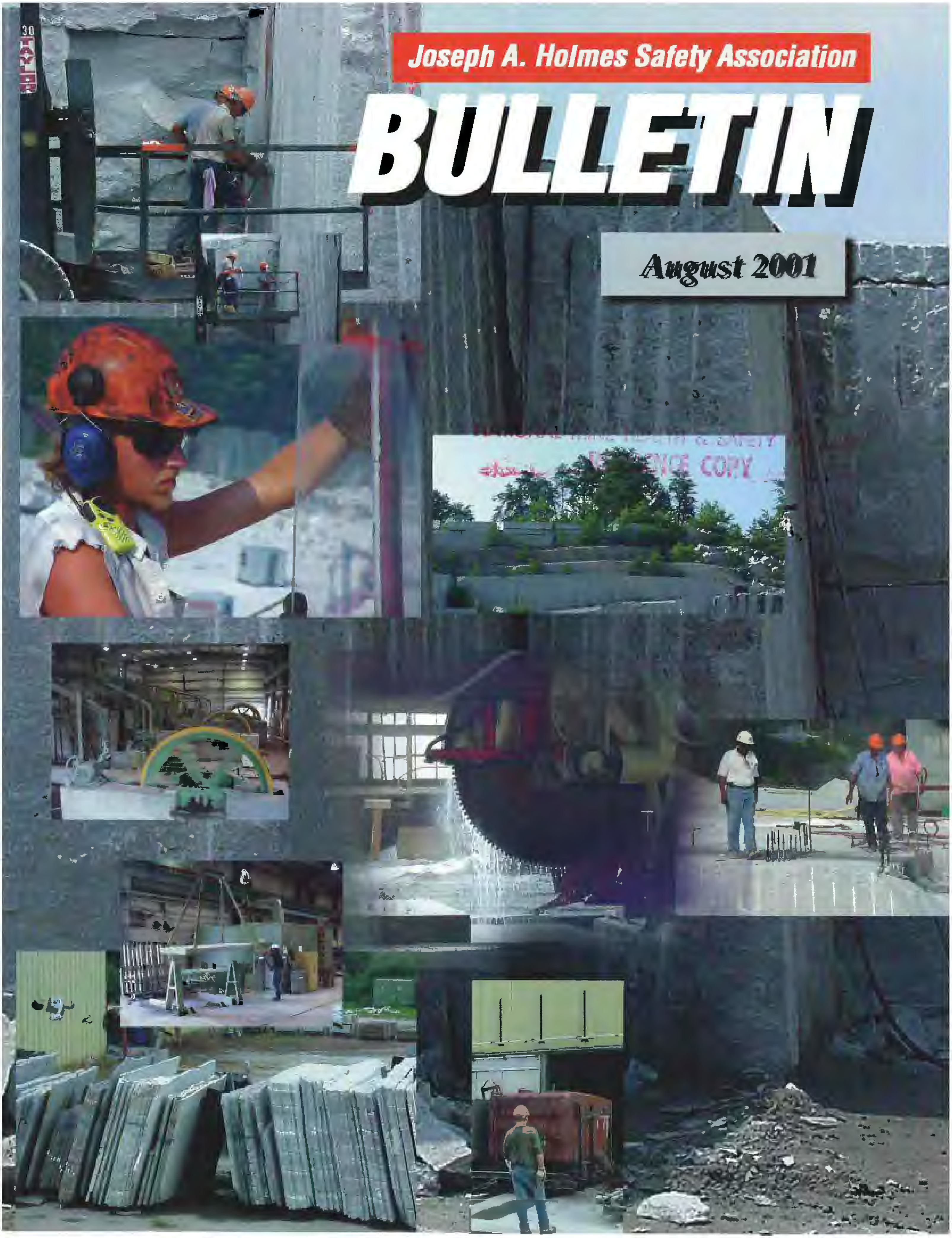

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