

OF MINING ACCIDENTS AND SENSE-MAKING: TRAVERSING WELL-TRODDEN GROUND

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ABSTRACT

Notwithstanding the huge contribution of the mining sector to the fiscal wellbeing of the host country, mining remains a perilous affair. Mining Houses make substantial investments and take drastic actions to the point of temporarily closing shafts or mines in an attempt to improve safety and reduce fatal accidents. Despite these initiatives the poor safety record of precious metal mines appears to persist. This suggests that the frameworks traditionally employed to interpret and make sense of mining accidents are probably inadequate. The study set out to explore the causes of a 'fall of ground' accident in a platinum mine in which a team leader was injured, and did so from a sense-making perspective. Content analysis of the narrative obtained from 10 key informants and a focus group (nine members) revealed that the multiple interconnected human and systemic causes appeared to have escaped detection, preventing a conclusive perspective on the causes of the accident. It is argued that mining investigations, as collective sense-making vehicles are subject to similar biases. The findings and implications are considered from the perspective of sense-making, and mindfulness.

CONTEXT

Mining is generally regarded as an 'affluent' industry and a significant contributor to the host country's Gross Domestic Product (GDP). For this reason it is an important source of stability and, by virtue of the scope of its operations, usually a mass employer and a powerful influence on societal wellbeing. In South Africa, where the current study was undertaken, approximately 2.9% of the economically active population is engaged in mining operations. Notwithstanding this significant contribution the industry is somewhat tainted by the high incidence of mining accidents and fatalities. It is not without reason that mining is the industry with the highest recorded number of fatal occupational injuries (cf. McGwin et al., 2002; Oldfield & Mostert, 2007). From the position that a single fatality constitutes a catastrophe and that one fatality is one too many, it is noteworthy that South Africa recorded 168 and 128 mining fatalities for the 2009 and 2010 years respectively. For the same period a similar decline is noted in the number of South African mining injuries from 3673 to 3019, which is encouraging. The recorded number of mining fatalities and injuries, however, are not

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reassuring and represents an indictment of safety orientation and practice in the mining environment. The South African presidential audit (investigation) into mine safety and health concluded that “*The South African mining industry has a history of unacceptably high accident rates that result in fatal and disabling injuries*” and “*...the number of people that die from occupational injuries from well over 700 in the mid 1980's to the current levels of over 200. Of serious concern is that the fatalities have been steadily decreasing since 1995, but over the last two calendar years, the decrease stagnated with a negligible reduction in 2006 and an increase of about 10% more deaths in 2007*” (DME, 2008, p. 19).

While underground mining is undoubtedly a dangerous occupation (see also Perrow, 1999), this characterization of the industry belies the attempts by Governments and Mining Houses to improve mining safety. Government and regulators, for example, have introduced stringent measures in the areas of training, operating standards, and legislation with the sole purpose of affording mine employees greater protection from mining accidents (e.g. machine-related, slip and fall, and blasting accidents). In 2007, and following a particularly devastating mining accident, executives took the very costly decision to stop all mining operations at the largest platinum mine in South Africa. Paradoxically, injuries and fatalities continued to occur while mining executives continued to pour huge amounts of institutional resources into the containment and management of unsafe practices. This is not uncommon and even from early historical accounts it is clear that the significant risks involved in underground and deep mining endeavors have been an enduring challenge for mining executives. As a result, safety has been a central focus of mine management, not least as a consequence of political pressure to improve safety practices.

Mining accidents and sense-making

Safety has received extensive coverage in the behavioral sciences especially considerations such as safety climate (Beus, Payne, Bergman & Arthur Jr., 2010; Clarke, 2006; Neal & Griffin, 2006; Zohar & Luria, 2005), workplace psychosocial safety climate (Dollard & Bakker, 2010), safety outcomes (Nahrgang, Morgeson & Hofmann, 2011); safety management systems (Naveh, Katz-Navon & Stern, 2011) and the influence of safety values on safety outcomes (Newnam, Griffin, & Mason, 2008) to name a few. These studies, the majority of which were undertaken in sectors other than Mining (e.g. education, health, transportation) provide a powerful applied perspective on the interrelatedness of organizational safety practices and individual safety behavior. Less common, however, are studies that purposefully consider cognitive-behavioral mindsets (schemata) and the cognitive dynamics that precede, give rise to, and are enacted in workplace safety behavior, especially in mining environments. The latter perspective, instead, is evidenced in notions such as ‘sense-making’ and ‘mindfulness’ in high risk or high-hazard institutions and technologies, and is prevalent in the work of, for example, Weick (1995; 2001; 2004) and Weick and Putnam (2006) on sense-making and mindfulness. Normal accident theory’ (Perrow, 1999), Catastrophe theory (Souder, 1988), Disaster theory (Stein, 2004), and Nonlinear change theory (Van Tonder, 2006; 2008) are some of the typical theory frames with which potential catastrophic failure in high risk and high reliability organizations have been approached. From the vantage point offered by cognitive-behavioral theory, mining safety has received only cursory attention yet offers substantial scope for deciphering entrenched behavioral phenomena. The current study employs the construct of ‘sense-making’ (Weick, 2001) as a novel perspective on the ‘dynamic equilibrium’ that appears to have stabilized around continuous investment in safety initiatives yet also recurring mining accidents and fatalities – in particular as this pattern recurs despite extensive investigative processes (and purported institutional learning) that have aimed to curb the incidence of mining accidents.

However, as the statistics convey, the exhaustive safety investigations that follow mining incidents and/or accidents do little to meaningfully alter this dynamic. The Presidential audit (DME, 2008) commissioned in South Africa after the 2007 mining accident concluded that not all major hazards were identified and that the approach of most mines to safety risk management “*is a major cause of concern*” (p. 61). Disturbing as this finding may be, it is unsurprising, and for several reasons. Carroll (1995) for example has concluded that incident review programs have many weaknesses, which are evident in part in the inability of these investigations to establish root causes - despite extensive training of investigators in root cause identification. Moreover, as Perin (1995) suggested, the focus on surfacing root causes during incident reviews

in 'high-hazard production systems' (p. 157) was heavily biased towards technology while systematic or contextual investigation received very little attention. This is problematic as the risks associated with errors in high-hazard organizations (e.g. mining companies) preclude the option of learning by trial and error, thus prompting an inordinate but justified reliance on minor, ad hoc incidents or accidents as primary vehicles for learning (Carroll, 1995; Sitkin, 1992; Weick, 1987). Naturally, and in compliance with mining standards, every incident in a mining environment is the subject of rigorous investigation. This is usually undertaken by an investigating team comprised of safety personnel and the relevant line supervisors, who will systematically investigate and reconstruct the incident, relying, among other, on available eye witness accounts. New procedures and standards typically follow from the insights generated during the investigative process and these are usually incorporated immediately into existing training programs. The intent, process and character of the inquiry into the incident (e.g. accident) are such that the root causes of the incident / accident should be established unambiguously. Yet, despite this procedural framework, 'learning' from such investigations do not meaningfully reduce the number of injuries and fatalities, prompting skepticism around organizational learning capability (i.e. sense-making capability – Battles et al., 2006; Sitkin, 2010). The ongoing injuries and fatalities suggest an inability to develop an appropriate understanding of the circumstances that give rise to the accidents (i.e. an inadequate sense-making capability). Secondly, and undergirding the imperfect nature of investigative procedures, is the readily acknowledged notion that sense-making is idiosyncratic. Consequently, the processes whereby employees develop an understanding of confusing events and information are decidedly individualistic – to the extent that marked differences are observed in the meanings that they attach to the same situations or events (cf. Helms Mills, Thurlow & Mills, 2010; Weick, 1995). Moreover, sense-making is a directional process in that it defines the framework through which, for example, management views and interprets otherwise seemingly inconsistent and ambiguous situations, events or information (Möller, 2010, p. 365). A caveat here is that sense-making may not always be helpful and may actually contribute to inappropriate conclusions (Stein, 2004). For our purposes, sense-making is regarded as those cognitive processes through which individuals develop/construct a plausible, logical and coherent account of an otherwise illogical, incoherent and sudden or unexpected event.

Accident investigations ('incident reviews') are technically the only practical approach through which mining officials are able to learn about organizational inefficiencies and systemic risks, but as several researchers indicate these analytic procedures are fundamentally flawed and incapable of revealing the key underlying causes of such accidents. The impact and profound ramifications of mining injuries and fatalities on the other hand necessitate an urgent consideration and exploration of any means that could ultimately reduce the incidence of these accidents. From this perspective the current research with its underlying concern with reducing mining injuries and fatalities, constitutes a critically important perspective as, after all, any injury or fatality is one too many! It is in this regard that alternative theoretical frameworks and/or approaches may assist with improved sense-making and in so doing shed more light on what appears to be a dynamic equilibrium between safety-related investment (expenditure) and ongoing injuries and fatalities, i.e. facilitate greater awareness of the avoidability of mining accidents and thus injuries and fatalities.

Against this setting the researchers hypothesized that sense-making around mining accidents are bound to be inadequate, resulting in fragmented and incomplete data and hence inappropriate conclusions. This it is argued, is particularly true for accident investigation panels that rely on post-accident 'evidence' led by employees. The current study consequently aimed to explore the causes of a recent '*fall of ground*' accident in a platinum mine during which a mining employee (team leader) was injured. Beyond this, and consistent with an interpretive research paradigm, the researchers refrained from formulating specific, pre-emptive propositions (to avoid bias and conceptual contamination), other than presuming that the use of a quasi-phenomenological approach will surface rich data which should allow more valid conclusions with regard to the cause of this accident and provide an expanded perspective from which to approach and consider mining accidents in general.

EMPIRICAL EXPLORATION

Research setting

The research was conducted in a typical mining operation in one of the 77 underground mineral mines in South Africa¹. The work methods and work environment of mining have hardly changed over the past three centuries. The commonly understood task of 'mining' (the ore body) essentially revolves around transporting people to and from the workplace, erecting infrastructure and installing needed support facilities such as water, electricity and ventilation systems, but also specific initiatives such as blasting *raises*², *ledging*, and equipping *stopes*. Traditionally in the South African mining environment and in the mine used in this study, these tasks are performed by separate *specialist* teams e.g. *ledging* teams, who prepare the work area for the mining teams. Against this context the current study focused on a *fall of ground* or *roof fall* accident (Perrow, 1999) - also referred to as a "Hanging wall" accident. In mining terminology the *hanging wall* and *side wall* refers to the roof and side walls of the area from which the ore is taken, respectively. On an annual basis this category of accidents accounts for the greatest proportion of fatal accidents in South African mining (approximately 35% with 86 and 76 fatalities in 2006 and 2007 respectively - DME, 2008, p. 23). During a "Fall of Ground" (FOG) incident or accident the overhead ground and rock formations, and often those on the sides, cave in.

Design and Methodology

The study was approached from within an interpretive research paradigm and based on the ontological premise that reality is socially constructed. It is argued that mining employees interpret and respond to mining accidents on the basis of personal perception and sense-making and it is these idiosyncratic views that are the target of the study's exploratory focus and objectives. Knowledge of the causes and dynamics of the *fall of ground* accident, consequently, is embedded in employees' individualized sense-making actions i.e. their meaning construction of the accident. Against these ontological and epistemological assumptions the researchers opted for a field study design with face-to-face, semi-structured (audio-taped) interviews with mining officials and a focus group discussion with mine workers - all of whom were directly or indirectly involved with the accident being researched. Relevant supporting documentation and archival data, where available, were used to supplement interview data.

A purposive sampling strategy based on respondents' functional proximity to the accident, was used. This meant that employees who were part of the work team or were located in the chain of command above the work team were involved. The second requirement was that respondents should be familiar with this specific *fall of ground* accident. As a result, in-depth, semi-structured individual interviews were conducted with five (5) senior managers who were part of the Mine management team and had a responsibility for employee safety, three (3) successive in-line supervisors above the injured employee, the injured employee himself (a team leader), and the technical advisor for the specific shaft. A focus group discussion was conducted with the 9-member work team that reported to the injured employee (the team leader).

Prior to commencing with the interviews respondents were again made aware of the objectives and methodology of the research and the confidentiality of the data and anonymity of the respondents. They were also again offered the opportunity to withdraw from the research should they desire this. During the interviews the researchers asked each respondent to provide a step-by-step account of the accident and explored the respondent's understanding of the causes and consequences of the accident. This was also the focal point of the focus group discussion. The data obtained from the interviews and focus group discussions were then transcribed and basic content analysis, using an open coding approach, was undertaken. The data were analyzed by two independent researchers who then met to review and resolve any discrepancies that were in evidence after the independent analyses. Several important perspectives consequently emerged and these are briefly presented in the ensuing section.

Empirical observations

Thematic content and empirical observations derived from interview data are introduced with a brief overview of the 'fall of ground' accident. This is followed by an account of the reported causes of the accident and a tabular depiction of causes as nominated by the various respondents.

The 'Fall of Ground' accident

On the morning of 19 February a Team Leader (TL) of a *ledging* team was injured while inspecting the roof or ceiling area (the 'hanging wall') for loose rock formations in a newly blasted *stope*. One specific rock seemed problematic to the Team Leader who requested that the Miner³ be called to verify his concern. The team leader nonetheless continued testing the ceiling area by prodding it with a steel rod, when the rock suddenly dislodged and fell, causing him serious injury. Team members immediately assisted the injured team leader who was subsequently evacuated for medical treatment. In accordance with mining regulations the work area was immediately closed off for investigative purposes. The latter typically comprises an investigative panel that conducts interviews with key employees and mining officials (often as many as 20), usually for a period of two or more days⁴.

Causes of the 'Fall of Ground' accident

In response to the researchers' questions interviewed employees and officials presented a rich mosaic of different yet intertwined and overlapping cause-and-effect links, which did little to establish the exact cause of the accident with any measure of certainty (see Table 1).

Some respondents were of the view that pre-existing geological "faults" (or *ground conditions*) in the mining area were the root cause of the accident, while others considered *damage to the 'hanging wall'* as a result of blasting (explosives) by mining teams either 6 to 12 months before or, more recently (the previous day), as primary causes of the accident – especially given the prevailing ground conditions. The *Mine Overseer* affirmed the role of ground conditions but stressed that *incorrect work methods* and *inadequate training* were central considerations. He indicated that the *raise* team did not properly install roof bolts, which are used to attach various layers of unstable rock to the more permanent geological formations. *Employee non-compliance* with the prescribed procedures was cited on the basis of the known difficulty of getting the required volume of cement into the holes drilled for the roof bolts - evidenced in the number of unused cement bags observed in the work place (to curb wastage and reduce costs exact quantities of materials are issued to workers in accordance with previously established requirements). While concurring with this perspective, the *Shift Supervisor* also indicated *coercion* by supervisors as a root cause (e.g. threatening the mining staff if production delays or stoppages occur). The issue of coercion is probably best accounted for as *pressure for production*, which is considered by several officials as the primary underlying cause of the accident. This of course raises the issue of power and hence supervisory and managerial roles in the mining process. *Shift supervisors'* work norms and practices were implicated as a significant cause of the accident. Moreover, several safety officers in particular argued that the accident commenced with *inconsistent* or *ambiguous* safety-production '*messages*' by senior managers. In the latter instance, both safety and production messages are regularly communicated but often with contradicting intent e.g. emphasizing the overriding importance of safety but issuing instructions that reveal production as the primary and overriding concern. Apart from these different perspectives on the fundamental cause of the accident, employee *speed* and *haste* was also indicated as a main cause of the accident. This in turn related to various *human factors* that were considered by some to be the origin of the accident. *Fatigue* as a result of demanding physical labor and short rest periods compounded by the fact that a large contingent of employees on a daily basis travel long distances between the

mine and their residences with public transport and get very little sleep, was indicated by respondents as being quite common. It was also pointed out that production interferences (e.g. due to insufficient materials / equipment) can introduce delays which reduce the time within which the daily production target ('call') has to be achieved. Employees may only leave their work areas when the daily 'call' has been completed. This often results in time overruns with employees consequently missing their public transport, which introduce associated, added difficulties e.g. the employee walking home. This takes up an inordinate amount of time and further reduces sleeping time, exacerbates fatigue and increases the probability of accidents. To avoid delays beyond normal closing times and be in time for public transport, the employees as a consequence start taking *procedural "shortcuts"* which will allow them to achieve the production call despite interferences. Commonly acknowledged by officials and employees, but not necessarily recognized as a human condition that contributes to accidents, is the *impact* and *psychological trauma* of mining accidents. A *fear* of underground work and *stress* are for example mentioned by *focus group members* and the *mine overseer* as primary considerations contributing to mining accidents. An outline of respondents' accounts of the fundamental cause of the accident, with supporting narrative, is presented in Table 1.

Generally the observations highlighted in Table 1 reveal substantial parallels with similar research, and in particular an earlier study by Souder (1988), which involved 60 carefully selected fatal-accident cases. Of the nine (9) variables that contributed in a statistically significant manner to fatal mining accidents, five (5) were echoed in the current study: supervisors evidencing a low safety norm; the absence of cautious behavior when performing tasks; victims failing to act in avoidance or evading the danger; the inability of victims to extract relevant information from a complex setting or background; and inadequate regard for personal safety (Souder, 1988, p. 6, Table 3).

Although first impressions suggest notable convergence around the perceived cause(s) of the accident, a conclusive *root cause* in this situation is not evident because of the level of ambiguity that envelopes the accident. Indeed, nuanced differences in mining officials' perspectives, on closer inspection emerge as consequential variation around the root cause of the accident. This, incidentally, is characteristic of systems with complex interactions (such as mining) and is "...most apparent in roof falls, or 'falls of ground' as they are usually called, a frequent and dangerous accident" (Perrow, 1999, p. 250). Typically sudden or "surprising" events in institutional settings of this nature develop over a period of time from a combination of multiple causes and circumstances rather than a single cause (Carroll, 1995, p. 181). The observance of multiple contributing factors to mining accidents is not novel, but perplexing because an unambiguous statement of cause is not possible. Not only does this suggest difficulty in making sense of mining accidents but it comments on the adequacy of the means (accident investigations) through which sense-making and organizational learning have to occur. Against this context, mining officials' sense-making in respect of this accident warrant further attention.

Table 1: Perceived central causes of the ‘Fall of Ground’ accident

No.	Causes of the accident	Illustrative narrative ^a
1	Pre-existing geological ‘fault’ line	<p>“...the ground is not good as the chrome is dominating in this area and might result in unstable ground (falling rocks)” (Resp. 6, Injured TL)</p> <p>“Due to our understanding and experience on the mine, the place was safe and this occurred as the result of natural soil events and was beyond human control” (Resp. 5, FGT)</p>
2	Earlier damage to the geological structure (6-12 months ago)	<p>“...the accident basically happened six months ago, or happened a year ago when they mined during the development stage, you understand? Its..., its where your accident started and, and hmm...” (Resp. 1, CSO)</p> <p>“Hanging wall was damaged six months back, injured badly”. (Resp. 4, MO)</p>
3	Recent damage (2 nd blasting) to the geological structure previous day	<p>“On this day, it was our second blast in the area and I think this had a negative impact on the incident” (Resp. 6, Injured TL)</p>
4	Poor workmanship(incorrect work methods in terms of drilling; attaching roof bolts)	<p>“Not using the air leg extension in the broad UG2 reef of 2m, forces you to drill upward and in so doing damaging the hanging wall”. (Resp. 4, MO)</p> <p>“Roof bolts are not properly installed, some are loose and do not even have cement on it. It takes 9 bags to fill a 2,2 hole, but they cannot get it all into the hole... they know it does not work and leave it as such” (Resp. 4, MO)</p>
5	Poor training in different mining methods	<p>“Developers at Merensky used to drill 10 cm above the reef. When drilling UG2 they want to do the same, which leads to damage to the hanging wall -... never coached to do it right” (Resp. 4, MO)</p>
6	Employee non-compliance with prescribed policies, procedures and standards	<p>“All the time people know... in 80% of the cases, of “fall of ground” incidents, they have identified the risk before the time, but ignored it. Yes, sometimes they are forced to carry on” (Resp. 2, SS)</p>
7	Negligence or unsafe conduct by individuals or teams e.g. speed, haste	<p>“It’s faster to install one eyeball and attach snatch blocks than it is to install three. A chain and snatch blocks ...negligence and hastiness to conclude the work... he knows he is taking a chance, but still does it” (Resp. 3, FTSR)</p> <p>“Guys are in a hurry to finish especially when there were shortages of material/resource. They do not want to wait at the ‘green areas’... they will miss their transport, they have paid for monthly public transport and if late they must pay for a taxi” (Resp. 4, MO)</p> <p>“People are lazy and want to take shortcuts to finish quicker” (Resp. 8, M)</p>
8	Pressure for production	<p>“If you talk to the production guys, they display a very strong production first and then safety” (Resp. 7, SM:AG)</p> <p>“People only think of the production...” (Resp. 1, CSO)</p> <p>“If a person does development work and production, for argument’s sake, he will leave the development [work] because a person only does work that drives his bonus in the short run” (Resp. 2, SS)</p> <p>“You can be as safe as you wish, but if the platinum does not come out of the ground, none of us will have work” (Resp. 7, SM:AG)</p>
9	The quality of supervision supervisor norms, practices	<p>“The Shift Supervisor creates norms by what he allows” (Resp. 2, SS)</p> <p>“...depends on the person above him [supervisor] if he’s really very strict, how safe his work is” ((Resp. 2, SS)</p> <p>“I think the miner/shift supervisor can do better at preventing incidents as they have better skills than employees at operator levels. They are blasting certificate holders” (Resp. 6, Injured TL)</p> <p>“Currently our suggestions are not listened to by our leaders and we are only instructed to do the job” (Resp. 5, FGT)</p>

		<i>"If I was there I could prevent the accident by following safer practices" (Resp. 8, M)</i>
10	Fear of supervisors (coercion)	<i>"The shift bosses force us to work in dangerous places..." (Resp. 1, CSO) "... and he says his shift supervisor told him that he would kill him if he does not keep that hole open" (Resp. 7, SM:AG) "...and when they leave, or look away, he just continues to do it [a life threatening act] because he is so afraid of his shift supervisor, who had said he will kill him" (Resp. 7, SM: AG) Yes, sometimes they are forced to carry on" (Resp. 2, SS) "If he does nothing I might give him a hiding tomorrow or something similar... this is the way it is..." (Resp. 2, SS)</i>
11	Ambiguous safety-production 'messages' by management	<i>"People preach one thing and do another - like talking about safety and then driving at 170 km past you on the road" (Resp. 3, FTSR) "You can be as safe as you wish, but if the platinum does not come out of the ground, none of us will have work" (Resp. 7, SM:AG) "...it is difficult to get the right message through; the monetary worth of high production is far more than the penalties related to safety" (Resp. 10, GFM)</i>
12	Human Factors - fatigue, lack of pride, maliciousness, personal problems, fear of underground work, stress, trauma, fear of prosecution, inattentiveness e.g. of the injured employee	<i>"Incidents, especially if you look at a stoping, in many cases it is very difficult, it is not only a case of being difficult, but it is hard work, the man is exhausted and he wants to now, he wants to finish" (Resp. 2, SS). "It is actually blatant maliciousness that allows incidents to take place"(Resp. 3, FTSR) "It could be that the person has personal problems and that his mind is not consistently on the job...he could have financial problems..." (Resp. 3, FTSR) "People come with problems to work, their attention is not applied to the risk and do not think of what can happen, but about their own problems" (Resp. 8, M) "No pride in their work - years ago it was as if the mine was your own" (Resp. 1, CSO) "Incidents are not good, we have seen people die or getting injured and as a result this leaves a lot of stress, trauma and fear of returning to work underground again" (Resp. 5, FGT) "I experienced FOG [fall of ground incident] when I was still working at the gold mines and I injured my hand – I have prayed that this doesn't happen again but it happened and it's a bad experience because you don't just forget about it" (Resp. 5, FGT) "The team now is negative and afraid to enter the mine again. They will wait for a higher level to make the place safe, but they must see it physically being done... you can see it touches them... affects their humanity" (Resp. 4, MO) "...most of the time that an incident occurs the guys stop the panel, so you lose the blast for the day, naturally. Hmm... hmm... I think it creates a bit of panic... because hmm, hmm... if you know... what the guy did wrong, am I not doing the same thing wrong? Am I going to be prosecuted?" (Resp. 1, CSO)</i>

Note. Illustrative narrative represents excerpts taken from transcribed interview and focus group data.
 "Job title acronyms used: *TL* - the injured team leader; *FGT* – the focus group comprising the team under the supervision of the TL; *M* – the miner, supervisor of the TL; *SS* – shift supervisor or 'shift boss'; *MO* – mine overseer; *FTSR* – full time safety representative; *CSO* –chief safety officer; *SM:AG* – safety manager: auditing and governance.

Mining officials' sense-making of the 'Fall of Ground' accident

In pursuit of greater clarity the various causes nominated by the respondents in Table 1 are further summarized and categorized in Table 2.

Table 2: Sense-making around the mining accident: Perceived central causes

No.	Salient causes of the accident	TL	M	SS	MO	FTSR	CSO	SM:AG	GFM	FGT
MINING TERRAIN (GEOLOGICAL STRUCTURE)										
1	Pre-existing geological 'fault' line	X								X
2	Earlier damage to the geological structure (6-12 months ago)				X		X			
3	Recent damage (2 nd blasting) to the geological structure previous day	X	X							X
CONDUCT & WORKMANSHIP										
4	Poor workmanship (incorrect work methods in terms of drilling; attaching roof bolts)	X	X	X						
5	Poor training in different mining methods		X		X					
6	Employee non-compliance with prescribed policies, procedures and standards		X	X	X					
7	Negligence or unsafe conduct by individuals or teams e.g. speed, haste		X		X	X	X			
MANAGERIAL										
8	Pressure for production			X			X	X		
9	The quality of supervision supervisor norms, practices	X		X			X			
10	Fear of supervisors (coercion)			X			X	X		
11	Ambiguous safety-production 'messages' by management					X		X	X	
HUMAN FACTORS										
12	Human Factors									
	• fatigue,			X			X			
	• lack of pride,						X			
	• maliciousness,					X				
	• personal problems,					X				
	• fear of underground work, stress, trauma,				X					X
	• fear of prosecution						X			
	• inattentiveness e.g. of the injured employee					X				

Note. Job title acronyms employed refer to the following: *TL* - the injured team leader; *FGT* - the focus group comprising the team under the supervision of the TL; *M* - the miner, supervisor of the TL; *SS* - shift supervisor or 'shift boss'; *MO* - mine overseer; *FTSR* - full time safety representative; *CSO* - chief safety officer; *SM:AG* - safety manager: auditing and governance.

From Table 2 it is evident that sense-making by the team leader and team members who work in the stopes, position the accident as a consequence of geological features and earlier damage to the hanging wall, but they fail to acknowledge broader systemic and dynamic influences on safe work practices (e.g. managerial conduct). By contrast, senior management's sense-making of the accident is structured around employee workmanship (negligence and non-compliance with work procedures), but sense-making at different managerial levels appear to be inconsistent. Sense-making by supervisory management (shift management) places managerial policies and practices at the center of the accident. Contextual considerations (geological features and the impact of previous mining operations) and human factors are virtually nonexistent in managerial accounts (sense-making) of the accident. In a similar vein, sense-making by respondents in the specialist safety roles (safety support function) tend to locate the cause(s) of the accident in the domains of managerial conduct and human factors, with minimal awareness of contextual (geological) considerations. These observations underscore both the idiosyncratic and directional i.e. role-based and framework-defining nature of individual sense-making (see Helms Mills et al., 2010; Möller, 2010; Weick, 1995).

However, accidents occur within, and are inextricably intertwined with a specific setting. Perception and hence sense-making, apart from being person-specific and selective, therefore cannot be divorced from the work environment and accident setting. Respondents' narratives were consequently scanned for evidence of inadequate or compromised perception of the accident environment as this may further impact on the accuracy, validity and consequently utility value of 'sense' (understandings) that may emerge during sense-making attempts. Evidence-based themes of such constraints, usually of an intrapersonal, interpersonal and/or institutional nature, were indeed observed (see Table 3 for illustrative excerpts of respondent narrative).

Table 3: Constraints on sense-making

No.	Constraints (Themes)	Illustrative narrative ^a
1	Anticipatory, forward thinking	<p><i>"Another thing with our people is that they frequently do not think ahead, they do not think of the consequences" (Resp. 2, SS)</i></p> <p><i>"People are not prepared for what may happen. We should learn to think ahead" (Resp. 8, M)</i></p> <p><i>"At the lower levels they simply do not think ahead" (Resp. 7, SM:AG)</i></p>
2	Reflective, retrospective thinking (and causality)	<p><i>... I think the guys do not think that far back...we could have prevented this accident at that time already... (Resp. 1, CSO)</i></p>
3	Learning from experience;	<p><i>"Hmm... well it worries me a bit that the repetitive things ... hmm the guys do not learn from their mistakes" (Resp. 1: CSO)</i></p>
4	Automated, routine-driven behavior (mindlessness linked to causality).	<p><i>"So the guy is now used to doing the work in this way, so he's been doing it wrong for some time...and this one time, it caught up with him" (Resp. 1, CSO)</i></p> <p><i>"The guy's doing something and he wants to finish it, then he stops thinking, he's just doing... that's when somebody gets hurt" (Resp. 2, SS)</i></p>
5	Perception and mindfulness	<p><i>"...then you still have to walk 15 km... you know, ...you know... you do miss a few things (Resp. 1, CSO)</i></p> <p><i>"He identified the danger of the working place, but thought it was safe to continue, he saw other loose rocks, but did not see the fault" (Resp. 8, M)</i></p>
6	Attentiveness / mindfulness	<p><i>"People only think of the production and do not stand back and pay attention to their surroundings." (Resp. 1, CSO)</i></p> <p><i>"It could be that the person has personal problems and that his mind is not consistently on the job...he could have financial problems..." (Resp. 3, FTSR)</i></p>
7	Inappropriate information processing (dissonance)	<p><i>"In 80% of the cases, of 'fall of ground' incidents, they have identified the risk before the time, but ignored it." (Resp. 2, SS)</i></p>
8	Institutional practices that stifle the unencumbered flow of relevant information.	<p><i>"It is possible if there is a flow of communication between leaders and employees and suggestions from all angles are taken into consideration" (Resp. 5, FGT)</i></p> <p><i>"Currently our suggestions are not listened to by our leaders and we are only instructed to do the job" (Resp. 5, FGT)</i></p> <p><i>"I think the guys hide things away, just because they do not want it to go to the topmost guy, so everywhere information is being blocked and in the end he does not develop a 'nice' picture" (Resp. 7, SM:AG)</i></p> <p><i>There is still a major culture of hiding things (Resp. 7, SM:AG)</i></p> <p><i>"I feel that the people immediately tries to cover up the issue as if it was not that serious. You know... and I think it is fear" (Resp. 1, CSO)</i></p>

Note. Bold emphasis added.

The themes indicated in Table 3 suggest that constraints to sense-making are located largely in the areas of *individual cognition* (attentiveness or mindfulness, perception, thinking or reflection, analysis) *employee behavior* (especially automated behavior – or 'scripts' cf. Ashforth & Fried, 1988) and *institutional practices*. Contrary to the dominant behavioral frame with which respondents portrayed the nature and causes of the accident (Tables 1 and 2), the illustrative excerpts in Table 3 draw attention to the cognitive 'world' that informs respondents' accounts. These comments are also at odds with the indicated 'cognitive behavior modeling' (*Group Effectiveness Manager*), and specifically the 'Stop, Think, Fix' mantra (*Resp. 3 FTSR, Resp. 2 SS*) that is taught at mining training centers. If an open systems frame is superimposed on the comments in Table 3, it becomes apparent that several deficiencies characterized employees' sense-making processes in respect of this accident. Sense-making is viewed here as consisting of data gathering, processing and exporting or outputting an integrated understanding or interpretation of the data. So, for example, the perceptual sampling of the work setting (data input process) appears to be impacted by inattentiveness, reduced presence of mind (mindfulness) and various distracting factors of a contextual or personal nature, further bolstered by automated and routine-driven behavior or 'scripts' (see themes 6, 5 and 4, Table 3). Even if cognitive processing was optimal, the potential value or sense that could be obtained from the analysis would be limited as a result of impoverished input data. Commentary, however, suggests that cognitive processing is not optimal. Active cognitive engagement and manipulation of input data appear not to be in evidence, gauging by the limited reflection ('thinking' - see themes 1 and 2) and flawed analysis or 'processing' (themes 3 and 7) conveyed by the commentary. Accurate and effective onward transmission of employees' integrated understandings (emergent 'sense' – the output process) in respect of the mining accident are unlikely because of the reported managerial disregard for employee perspectives and the institutional tendency to suppress undesirable data (see Theme 8). Compared to the dominant technology 'bias' of accident investigations (Perrin, 1995) these observations then suggest the need for an elaborated frame-of-reference when analyzing and making sense of mining accidents. This has several implications for ongoing research and institutional management, which are briefly considered in the ensuing section.

PERSPECTIVES AND IMPLICATIONS

The contribution of a sense-making perspective

Researchers have approached the root causes of mining accidents from many perspectives but very little attention has been directed at this situation from a sense-making perspective. The adoption of a sense-making lens in this (case) study of a nonfatal mining accident has proved beneficial in several ways. Among other, it has surfaced multiple intertwined causal linkages, both temporally and spatially removed from the accident. It also revealed the idiosyncratic and contained nature of individual interpretation frames and how these impose boundaries on the number and range of interpretation options available to those employees associated with the accident. Compounded by impoverished communication practices (see theme 8, Table 3), this naturally precluded an extended appreciation of the dynamics involved in the accident and adversely impacted both individual and collective sense-making processes. Although several mining officials seemed to be aware of circumstances beyond the immediate accident setting that contributed, they do not appear to have consciously sampled the total field, or to detect the extended frame and multiple linkages that tie together the potential causes they nominated (Table 2). This absence of systemic awareness is not uncommon (see also *systemic blindness* or the inability to detect crucial indicators of an impending crisis - Van Tonder, 2006). At the same time it is consistent with the position that sense-making during crises will be compromised because communication and feedback channels are constricted (cf. Theus, 1995; Weick, 2001). Indeed, multiple considerations contribute to the inability to anticipate impending crises, catastrophes and, in this instance, mining accidents. Systemic awareness and an appropriate internalized understanding of the organization are central considerations in preventing accidents, but 'blindness' are influenced also by the impact of past success (and extended accident-free periods in the mining setting), denial, distortions, self-deceit, paradigmatic fixation, and several other (cf. Brown & Jones, 2000; McLarney, & Dastrala, 2001; Van Tonder, 2006). In this mining accident employees at best grasped fractional linear sequences of cause-and-effect relations but failed to register and make sense of the multiple, interrelated causes of the accident which were dispersed across the

entire mine system - both spatially and temporally. The contribution of a sense-making perspective however extends beyond this elaborated perspective and suggests that formal accident investigation procedures will be impacted by flawed employee sense-making.

Accident investigations and flawed institutional sense-making

Accident reviews (or incident or event reviews) represent one of the very few institutional sense-making instruments available to mining officials. The application of a sense-making perspective however suggests that this instrument, in its current form, is prone to significant flaws and, except for the simplest of incidents or accidents, will not yield the required knowledge and understanding to prevent similar accidents from recurring. In this study the respondents closest to the accident (including the injured team leader) were engaged and, being the most important sources of data on the accident, these employees invariably lead evidence at accident reviews.

The nature of sense-making processes is such that individual employees, and the respondents in this situation, in order to understand and cope with the sudden or surprising event/accident, impose cognitive frames on accidents to 'make sense' of the situation. These frames introduce logic of some form to connect the various information strands sampled in the situation. From this a 'coherent understanding' is developed that aligns more with their belief systems than with the actual circumstances, conditions and features of the accident. Indeed, employees' sense-making are derived from their person-specific and belief-based perception and interpretation of the accident features (Brown & Jones, 1998; Helms Mills et al., 2010; Möller, 2010). Of particular importance is that the roles occupied by employees within the system will influence the vantage point, scope, breadth, and depth of his/her perception of the accident (cf. Möller & Svahn, 2006 who argue that actors' ongoing sense-making could be constrained by narrow role-based outlooks). As a result, employees' representations of facts e.g. to accident review panels, will constitute a post sense-making and hence a personalized and unavoidably altered representation of the facts... Their accounts or 'sense' of what happened are primarily retrospective reconstructions of the event, characterized by logic and coherence (cf. Battles et al., 2006; Weick, 1995). However, as Van Tonder (2004, p. 187) indicates, employees' perceptual appraisals of ambiguous situations (e.g. accidents) will invariably prompt misperceptions, which then promote further cognitive elaboration as part of the retrospective reconstruction of an 'understanding' of what transpired. This, invariably, is subject to multiple constraints such as inaccurate or incomplete perception and various cognitive distortions (recurring reasoning errors – see Van Tonder, 2004, pp. 119, 187). Emotive states ensure that these constraints are pervasive during the sense-making process and in this manner contribute to the idiosyncratic nature of individual accounts of the 'facts'. Given this data platform, the validity and reliability of the accident investigation panel's assessment - a collective, institutional sense-making initiative – and the conclusions and decisions that emerge from such accident reviews, will be compromised.

Mindfulness as precursor to sense-making

As useful as retrospective sense-making may be, in the accident considered in this case it did not allow for a conclusive and coherent understanding of the root causes of the mining accident to emerge. Indeed, as the perspectives obtained from the respondents indicate, effective sense-making is not apparent. Commentary by functionaries (themes 1 to 6, Table 3) instead indicate behavior that "*...is performed automatically or mindlessly thus underscoring the oft-noted limitations of cognition in task and role-based behaviors*" (Ashforth & Fried, 1988, p. 322). Mindless behavior entails entrenched routines or 'scripts' (cf. Ashforth & Fried, 1988) of sequenced behavior that are enacted in seemingly similar (repetitive) situations and are reinforced with every occurrence where the automated enactment of the 'routine' appears to work successfully i.e. without adverse consequences. Eventually employees habitually apply automated routines to situations that appear similar, but are more intricately connected and have greater risk attached yet remain undetected, which then result in a significant failure, accident or catastrophe (e.g. in situations of 'tight coupling' – Perrow 1999; or 'descriptive complexity' – Van Tonder, 2006). To avoid such situations Weick

and Roberts (2001) suggested the notion of *collective mind* whereby employees have to interrelate substantially to *construct* a commonly understood and mutually shared 'field' or environment. However, collective mind in itself may be an insufficient condition for the timely sampling of accurate accident-relevant information - if Krieger's (2005) position on *collective mind* and *shared mindfulness* is considered. Unlike collective mind that concerns the social construction of a common field or environment i.e. the accident and its context, shared mindfulness propounds the sharing of an *accurate* depiction of the 'field' or environment (operating context) in which the accident occurred. Shared mind has the added feature that employees would simultaneously be in an "attending state of perceiving that is continually open to incoming data" (Krieger, 2005, p. 156). Given the strong power-production cultures evident in mines, anything less runs the risk of promoting what Geiger and Antonacopoulou (2009) refer to as self-reinforcing and self-legitimizing narratives or 'truths' that are beyond questioning and which will promote so-called 'blind spots' and organizational inertia.

Implications for institutional management

Applying a sense-making frame to the mining accident explored in this study highlights several risk areas that are not pertinently identified and addressed in studies of safety climate and safety performance. These risks related to individual cognition and idiosyncratic retrospective sense making, which are not adequately attended to during institutional accident investigations either. The predominantly behavior and technology foci of these retrospective accident investigation panels - in itself a sense-making process - do not adequately account for the limitations embodied in the perceptions, interpretations and subsequent personal meaning creation, i.e. sense-making, of employees. The latter, as argued, tacitly but forcefully inform workplace behavior. The risk however is not limited to the accuracy and adequacy of individual sense-making only, but extends to the *collective* construction of an *accurate* representation of the accident circumstances, and these are largely premised on individual understandings of the event.

The challenge for Mining Houses consequently resides firstly in the cultivation of an appropriate, habitual state of awareness among all those involved in these situations and, secondly, to establish accurate and authentic information sharing in century-old power-and-production cultures.

To secure a state of collective and shared mindfulness a significant change in managerial mindsets and attitudes, with a substantive commitment to a safe, fatality-free work environment (Towsey, 2003), reified through appropriate systems and policy changes, are mandated. An approach that embodies the challenges of cognition, especially around improved accuracy of observation skills and perception, may assist in cultivating greater mindfulness and consequently contribute to improved individual and collective sense-making. Formal management education could certainly be reviewed and augmented to incorporate elements of systemic awareness; mindfulness and hyper vigilance (cf. Van Tonder, 2006) – acknowledging also that the impact of conventional training in this setting is not entirely effective (or certain - cf. Monforton & Windsor, 2010). Much can be gained from a careful consideration of similar practices in the air traffic control industry where situational awareness and related skills have been a primary focus for decades (cf. Carstens et al., 2008; Van Tonder, 2008). At the same time, extensive training and retraining – to the point of habit - of non-managerial mining employees in observational and cognitive skills beyond the current ineffectual 'Stop, Think, Fix'-mantra of the mining community, would serve a powerful role. Indeed, from this account it seems necessary to enforce an 'Observe and Think' component before invoking this mantra.

CONCLUDING PERSPECTIVE

On the basis of the high incidence of occupational injuries and fatalities, the Mining industry is generally considered to be the most dangerous of the various employment sectors. Political sensitivity around injuries and fatalities in the South African mining environment has steadily increased over the past decade and is likely to become a worldwide concern. The probability of a single fatality at some stage in the future becoming a tipping point and prompting political intervention and/or the premature closure of otherwise

productive and profitable mining operations cannot be disregarded. In an attempt to gain insight into the apparent equilibrium that seems to have stabilized around safety-related investment (expenditure) and ongoing injuries and fatalities in South African precious metal mines, the current study set out to explore the causes of a 'fall of ground' ('hanging wall') mining accident from a micro-level sense-making perspective. The qualitative research methodology employed in this very focused and contained study preclude any form of generalization, but the findings do suggest that mindsets and habits are far more pervasive and enduring than is generally acknowledged. Indeed, human neglect and error in the domains of perception, mindfulness and sense-making currently manifest in ways that will prevent appropriate institutional sense-making with regard to accidents and will preclude needed changes in relevant policies and practices.

Unless a meaningful, sustainable commitment to mining safety is made, the lure of gold and platinum will lead through well-trodden ground... and consistent with 'senseless' practices, is bound to be fatal for some unsuspecting employee.

ENDNOTES

1. The mineral industry in South Africa can be dissected into five broad categories i.e. gold, the precious metals group (PMG), diamonds, coal and vanadium. The Department of Minerals and Energy (DME, 2008) suggests that the safety hazards in the Gold and Platinum sectors are predominantly associated with rock falls and rock bursts as a result of mining at great depths; the interaction of people and machines in confined spaces; falling materials and rolling rocks; inundations by mud or broken rocks; falling into excavations or from structures; exposure to dust, gases and fumes; explosives and fires; seismicity and high temperatures (up to +60°C if uncontrolled).
2. Terminology commonly in use in the mining environment and used in this paper include:
Hanging Wall: Refers to the ceiling of an underground mining tunnel or 'stope'. New 'tunnels' are developed through blasting with explosives, clearing out the metal carrying ore and reinforcing the ceiling / hanging wall with wooden supports.
Footwall: The ground surface of the working area (where the ore is extracted)
Stoping: The activity of removing ore, which creates stopes (tunnels in the mining area)
Raise: A tunnel that is cut into the rock to link work areas, enable movement of mining staff between work areas, and bring fresh air into the work area.
Ledging: Is the activity opening and equipping a mining tunnel or stope for production purposes.
3. Team Leaders constitute the first level of supervision and are usually responsible for the direct supervision and safety of a team of 12 employees. Several team leaders (five or six) report to a Miner who reports to a Shift Supervisor. The latter supervises between four and six miners and in turn reports to a Mine Overseer with a similar span of control (five or six Shift Supervisors).
4. Clarifying and contextual commentary provided by the *Group Effectiveness Manager* of this platinum company, during an in-depth review of the data and empirical observations pertaining to this specific accident.

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