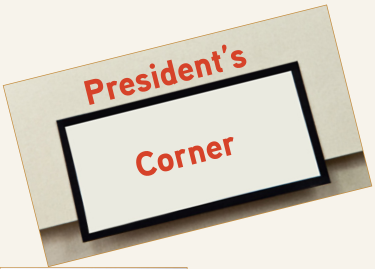

Quest for zero harm in South African deep gold mines

On 5 April, 2024, I had the privilege of attending the Fall-of-Ground Action Plan (FOGAP) Day of Learning — an event that marked a significant milestone in the pursuit of mine safety. Hosted by the Minerals Council - South Africa (MCSA) in partnership with the Association of Mine Managers of South Africa (AMMSA), the South African Colliery Managers' Association (SACMA), and the South African National Institute of Rock Engineering (SANIRE), the event showcased groundbreaking strategies to combat fall-of-ground incidents, which remains one of the most significant hazards in mining operations.

FOGAP was developed through the collaborative efforts of the MCSA Rock Engineering Technical Committee (RETC) and SANIRE and is aimed at eliminating fall-of-ground fatalities. The focal points of the day's discussions were on innovative support systems and improved workplace conditions.

I was particularly impressed by the adoption of permanent mesh support in narrow tabular stopes. This innovation involves securing high tensile steel mesh to the hanging wall using an array of supports including rockbolts, timber props, timber packs, and mechanical props (Figure 1). While rockburst resistant supports, such as rapid yielding hydraulic props and engineered timber props, have been employed for many years, they have not entirely mitigated the risk of fatal injuries during rockbursts, as the rock tends to fail between these supports. Integrating the high tensile mesh into the support system could significantly reduce the risk of injuries and fatalities.

Figure 1–High tensile steel mesh installed in stopes (left – courtesy: Sibanye Stillwater; right – courtesy: Harmony)

The challenge of installing mesh in narrow tabular stopes has been a topic of concern since I began my career in the 1990s. Due to the manual labour required, often in hot and humid conditions, and the complexity of the installation process, the task was deemed too difficult. Mesh installation is common in tunnels where stress and rockburst damage is a concern; where the mesh is fastened to the rock using rockbolts and sometimes high tensile steel cable lacing.

The landscape began to change around 2012 when in-stope rockbolting became widely adopted, allowing for support to be placed closer to the stope face and increasing the density of support. Coupled with the development of high tensile mesh, the installation process has become slightly more manageable. However, it's important to acknowledge that poorly installed mesh can exacerbate safety risks, making the development and trial of installation methods critical. Once proven effective, it is imperative to train all stope teams in these methods. Not surprisingly, convincing labourers of the benefits of this additional effort is no small feat. It requires effective communication and demonstration—rolling out such significant changes is a considerable achievement that could substantially contribute to the goal of zero harm.

Another noteworthy advancement is the introduction of LED lighting, which has drastically improved the illumination of underground stopes. These low-power lighting systems can be installed swiftly at the start of a shift and are removed at the end to avoid damage from blasting and scraper cleaning. The enhanced visibility allows for easier identification and remediation of rockfall hazards, further bolstering workplace safety.

Figure 2 illustrates the annual number of seismic-related fatalities in the industry since 1984, revealing a pronounced decline from 147 fatalities in 1990 to none in 2022, which at first glance indicates a dramatic enhancement in workplace safety. However, a more nuanced view is warranted. A substantial portion of rockburst incidents occur in gold mines, often deeper than 2000 metres. Concurrently, there has been a notable decrease in both gold production and workforce within the gold mining sector (Figures 3 and 4). South Africa's gold production peaked in 1970 at one million kilograms of gold, the highest recorded by any country in a single year. This figure has since steadily declined to just 100 000 kilograms by the end of 2023. Similarly, the workforce in gold mines has diminished from nearly 400 000 individuals in 1995 to 93 589 by the end of 2023.

The question then arises: Does the decline in fatalities accurately reflect enhanced safety measures, or is it merely a consequence of the contraction of South Africa's gold mining industry? For a more reliable evaluation of safety performance,

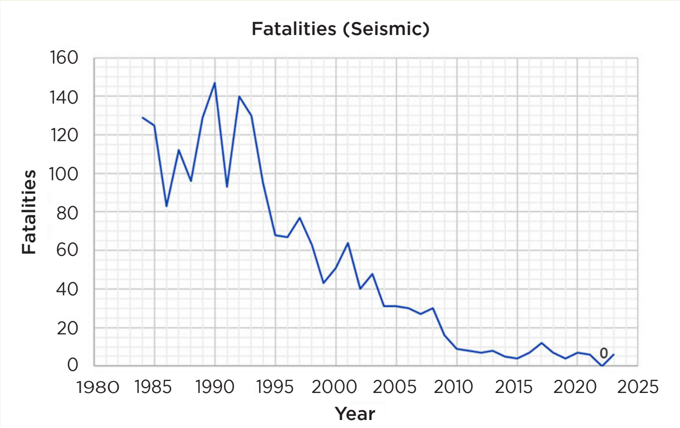

Figure 2—Fatalities caused by seismic events in South African Gold Mines from 1980 to 2023 (from Minerals Council and SAMRASS database)

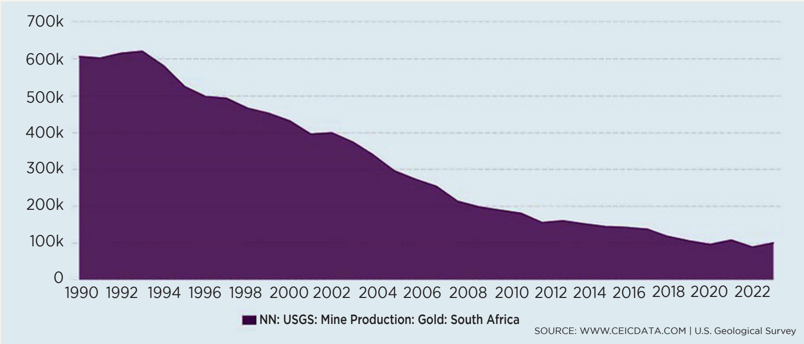

Figure 3—Gold production in kilograms (https://www.ceicdata.com/en/indicator/south-africa/gold-production)

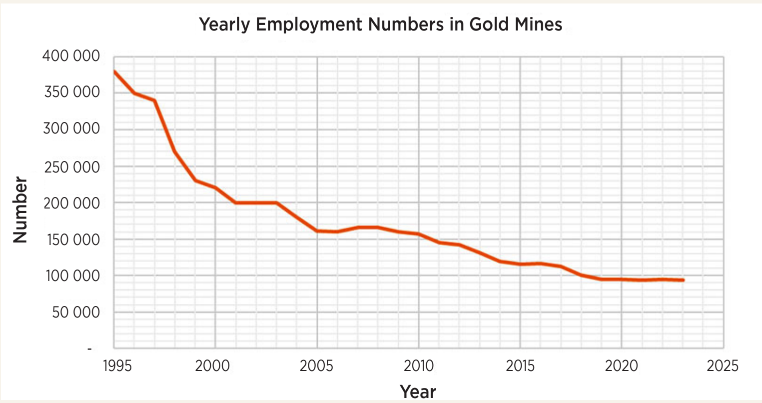

Figure 4—Yearly employment numbers in South African Gold Mines (Stats SA and DMRE)

it is imperative to control for certain variables. Historically, the MCSA reported fatality rates per 1000 workers, but this metric was later changed to reporting the absolute number of fatalities to emphasize the human cost and foster greater empathy. While the latter approach has its merits, it complicates the task of objectively assessing improvements in safety.

In Figure 5, I have normalized the fatality figures to account for every 100 000 workers and per 100 tons of gold produced. These reference points are chosen for their approximation to current gold production and employment figures. Furthermore, this method aligns with the World Health Organization's practice of standardising death rates per 100 000 individuals, enabling comparisons with other mortality causes. Although this normalization could benefit from more specific data, it offers a more reliable preliminary analysis of safety advancements. The data indicates a gradual decline in fatality rates from 1990 to 2008, followed by a noticeable shift between 2008 and 2010. Presently, the rate hovers around five fatalities per 100 000 workers, with 2017 and 2020 being particularly challenging years, and 2022 being remarkably safe with no reported fatalities.

President's Corner *(continued)*

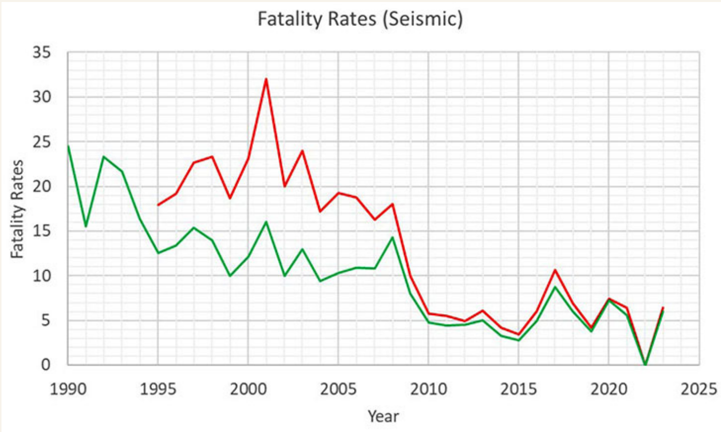

Figure 5—Normalized fatality rates

This analysis also reveals that year-on-year comparisons may not yield substantive insights, whereas long-term trends are more telling. The observed improvements are likely the result of various interventions, both technological and managerial. The MCSA, in collaboration with the mining industry, has launched several safety initiatives through the Mine Occupational Safety and Health (MOSH) programmes and, more recently, the FOGAP initiative. The future will determine if these efforts will lead to further advancements in safety.

In light of the reduction of fatality numbers, both due to contraction of the industry and safety improvements, it is necessary to shift focus towards tracking high-potential incidents to monitor safety performance. Large seismic events and major rockburst damage continue to be prevalent in deep-level gold mining operations, posing a persistent challenge in addressing the risk. Rockburst risk management requires a comprehensive strategy that encompasses multiple components. Each of these components makes a small contribution to reducing the risk, but when all are implemented, it results in a significant reduction in risk. These include optimising mining layouts and sequences to reduce the frequency of large seismic events and to redirect them away from active mining areas, modifying the characteristics of the rock (pre-conditioning) to reduce the likelihood of bursting, improving support to reduce the likelihood of damage caused by large seismic events and reducing the exposure of workers to rockburst damage.

Guidelines for optimising mining layouts and sequences have been developed over many years, together with numerical modelling tools to analyse stress changes caused by mining. However, the geological structures (faults and dykes) and rock mass characteristics are complex, and therefore the rock mass response will vary in different parts of the mine and between mines. It is important to gather as much information on the geology as possible and to develop structural models to better anticipate the rock mass response. Seismic monitoring systems are essential tools for measuring the rock mass response and evaluating the implementation of rockburst risk management strategies throughout the mine.

Unfortunately, the technology to predict the location and time of a large seismic event has not been developed, despite significant efforts in this regard. If it were possible to do this reliably, it would enable the removal of workers from the danger area before a significant rockburst. At present seismic monitoring systems can reliably measure changes in seismic behaviour, which may provide an indication of an increase in seismic hazard in an area of the mine. However, seismic monitoring systems have contributed immensely to understanding rock mass behaviour and reducing uncertainty, and continue to play a key role in rockburst risk management.

Through the FOGAP programme, the MCSA has initiated a seismic research project. The first phase of the project is in progress, which entails the review of current rockburst risk management practice, locally and internationally. The objective of this phase is to identify best practices and gaps which need to be addressed. While rockburst risk management practices were first developed in South Africa, international mines are going deeper and do experience high stress and high levels of seismic hazard, so there is an opportunity to learn from different approaches applied elsewhere. The second phase will involve the investigation of alternative methods for short term seismic hazard analysis using machine learning and Bayesian statistical methods applied to seismic monitoring data. Ultimately this will lead towards much improved guidelines on rockburst risk management, and training of rock engineers to implement these guidelines.

It is imperative to strive for zero harm and to implement practicable solutions to reduce the risk. Risk is the product of probability and consequence. Since probabilities are expressed as fractions, a probability of zero equates to one divided by infinity, which is mathematically unattainable. However, safety interventions may make the probability of occurrence so low that the resulting injuries and fatalities within the population of mine workers would be so infrequent as to result in effectively zero harm.

W.C. Joughin
President, SAIMM