MINERALS COUNCIL
SOUTH AFRICA

FOGAP
NEWSLETTER

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SEISMICITY

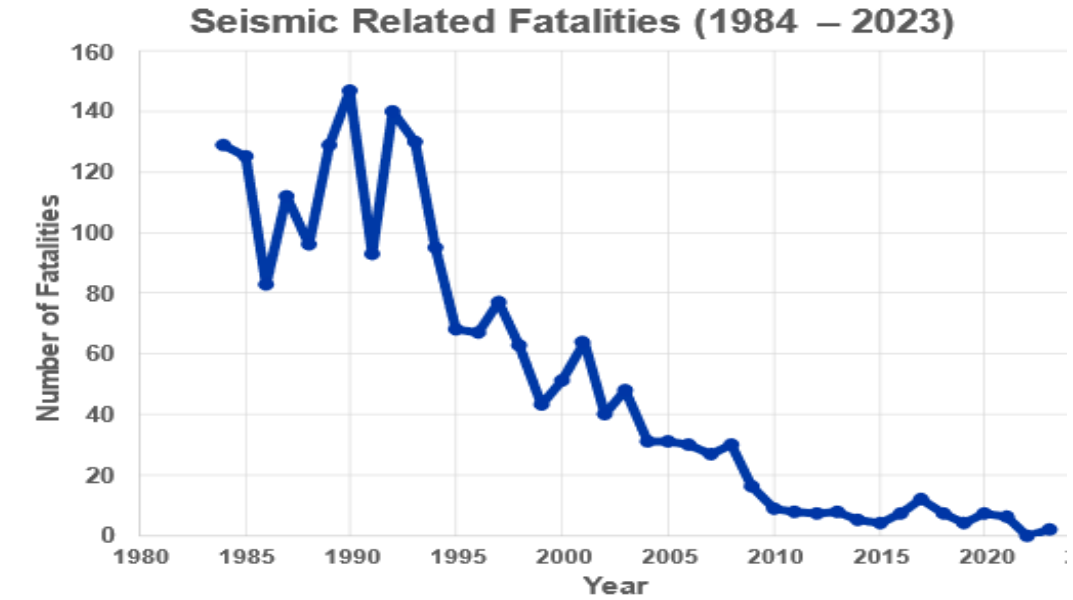
History of dealing with seismicity

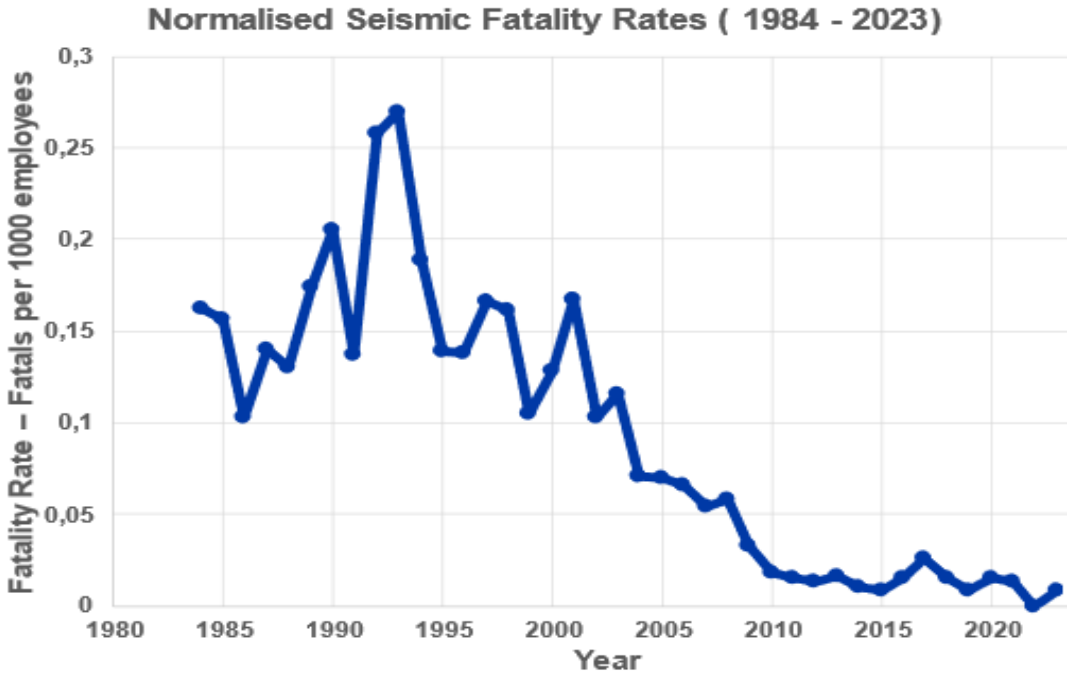
Rock is not infinitely strong. It will fail if sufficiently high stresses are applied to it. Depending on the rock type, this stress will vary.

With hard, brittle rocks that sustain high stresses, when they fail the energy release may be rapid and damaging.

When visible failures of rock occur underground, they are referred to as a **strain burst** or a **rock burst**, depending on the amount of damage.

These bursts can injure or kill mine employees in the vicinity. Understanding rock stresses, seismicity, and reducing risk and exposure by miners to these dangers is a major area of work both locally and abroad.





The history of fatal accidents associated with seismicity, particularly in deep-level hard-rock mining, is cause for reflection.

These graphs on the left show the number of seismic-related fatalities and the fatality rate per 1,000 workers between 1984 and 2023.

There are significant improvements in both sets of data. This has been due to on-going research and developments in understanding seismicity at mines.

.Although the figures at present are low, there is still a need to apply more effort in this area to achieve zero harm from this cause.

South African mines are among the deepest in the world, with the Mponeng gold mine near Carletonville the world's deepest at 4km below surface. As companies move to ever deeper reserves, understanding and managing seismic risks becomes increasingly more important.

The Minerals Council has launched a research project through the FOGAP Programme to improve seismic hazard ratings and warning systems to create a benchmark standard.

South Africa has made significant improvements in reducing the number of underground fatalities stemming from seismic events but as mines go deeper and technologies develop, it is critical that the local industry adopt global best practices.

William Joughin, a partner at **SRK Consulting** with more than three decades of experience in underground rock engineering, is a key member in the research team undertaking a review of South Africa's seismic hazard rating and warning systems.

"We've not been successful at predicting seismic events. It's just something that's incredibly difficult to do. Predicting seismic events is the holy grail of rock engineering, but so far, it's proved an elusive and difficult problem. Even seismologists studying earthquakes cannot accurately predict the energy and moment of earthquakes.

"Our short-term seismic hazard assessment approach is generally not reliable as a prediction tool. It might give us an indication in a change of behaviour but not necessarily predict a large seismic event, and generally, current methods and systems are not significantly better than random." he says.

William Joughin
Partner at SRK Consulting

It is based on the premise that a change in the pattern of microseismicity (energy, moment and event rates) occurs a few hours before a large seismic event. When certain patterns are observed, this triggers a warning, and mines will prevent workers from entering the affected area or implement some other method of risk mitigation. However, rockbursts still occur without any warning and false alarms are common.

We are much better at identifying hazardous areas and implementing strategies to manage the medium- to long-term risk.

Changes to mining layouts minimise the effect on seismically active geological structures and improved support systems mitigate rockburst damage as a result of a seismic event. Rock engineers use sophisticated computer programmes and mathematical models to analyse and calculate the stress changes on geological structures as a result of mining. Seismic monitoring enables rock engineers to evaluate the effectiveness of their risk mitigation strategies. Back analysis of large seismic events enables rock engineers to determine the source mechanisms, which also helps to understand how the stress changes associated with mining influence seismicity.

"There's a good opportunity for us to learn from other miners internationally and service providers," says Mr Joughin, listing the Institute of Mine Seismology (IMS), Australian Centre for Geomechanics (ACG), SRK and South Africa's Centre for Scientific and Industrial Research (CSIR).

During 140 years of mining, South African companies learned a great deal about seismic risk management. As these companies expanded offshore there has been a level of migration of overseas technologies and methods to local mines.

As mines around the world have deepened, adapting layouts and mining methods to suit their orebodies, their techniques of managing seismic risk have developed, providing sources of information for local miners.

South Africa's mines have vast underground layouts to extract the tabular reefs. Offshore mines tend to have fairly concentrated orebodies, giving them denser seismic networks with more sensors per cubic kilometre and often better 3D arrays. "Our three-dimensional location activity is generally not as good as those internationally."

Source mechanisms cannot be calculated reliably without good 3D location accuracy.

"We certainly have the ability to calculate source mechanisms, but our networks make it difficult to do it reliably. The only way to fix it is to improve the 3D arrays. The review will make those practices more widely known as we look at an industry best practice standard."

Motivation for the project to research seismic hazard rating and warning systems

Approximately a quarter of total rock-related fatalities and injuries are caused by seismic events such as rock bursts.

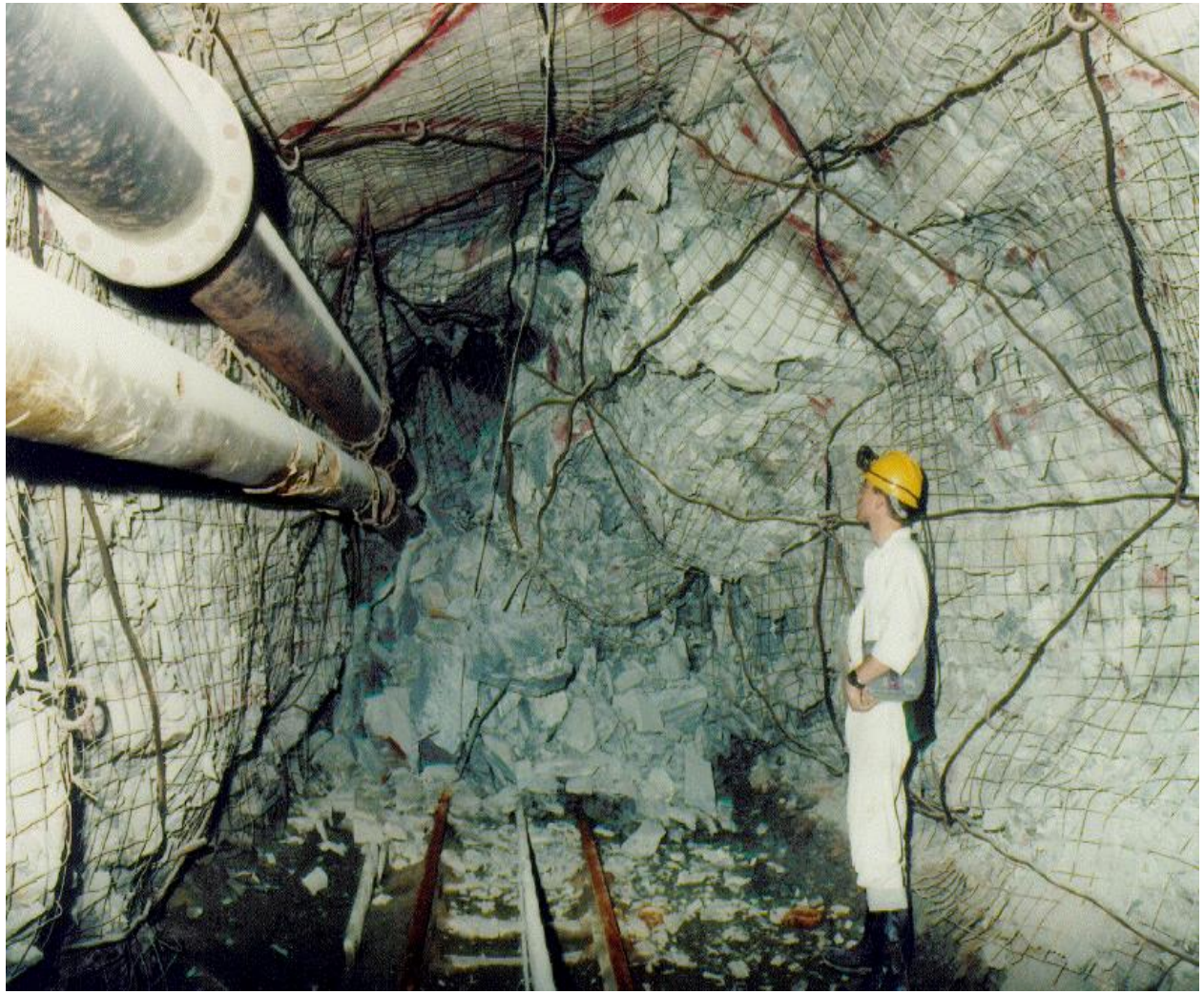
It is expected that these seismic phenomena will increase and continue to be of major concern in the ever-deepening gold and platinum sectors during mining and when mining is done close to certain geological structures.

The South African Mining industry has invested considerable resources in understanding the seismic threat in the mines, particularly the deep gold and, to a lesser extent, the platinum mines, through the MHSC research programmes and private mining company investment.

Some mines have installed state-of-the-art seismic systems to track seismic changes as mining progresses and have been successful in enabling deeper understanding of the management of the seismic risk.

This is partly demonstrated by the reduction in rock burst-related deaths in the past two decades.

Any seismic warning information obtained by systems that assist in identifying higher-risk areas should be able to transfer the information to the area of concern in real time to ensure a timeous and appropriate response. Safety of employees depends on mines ability to respond quickly and effectively.



The need for best practice guidelines

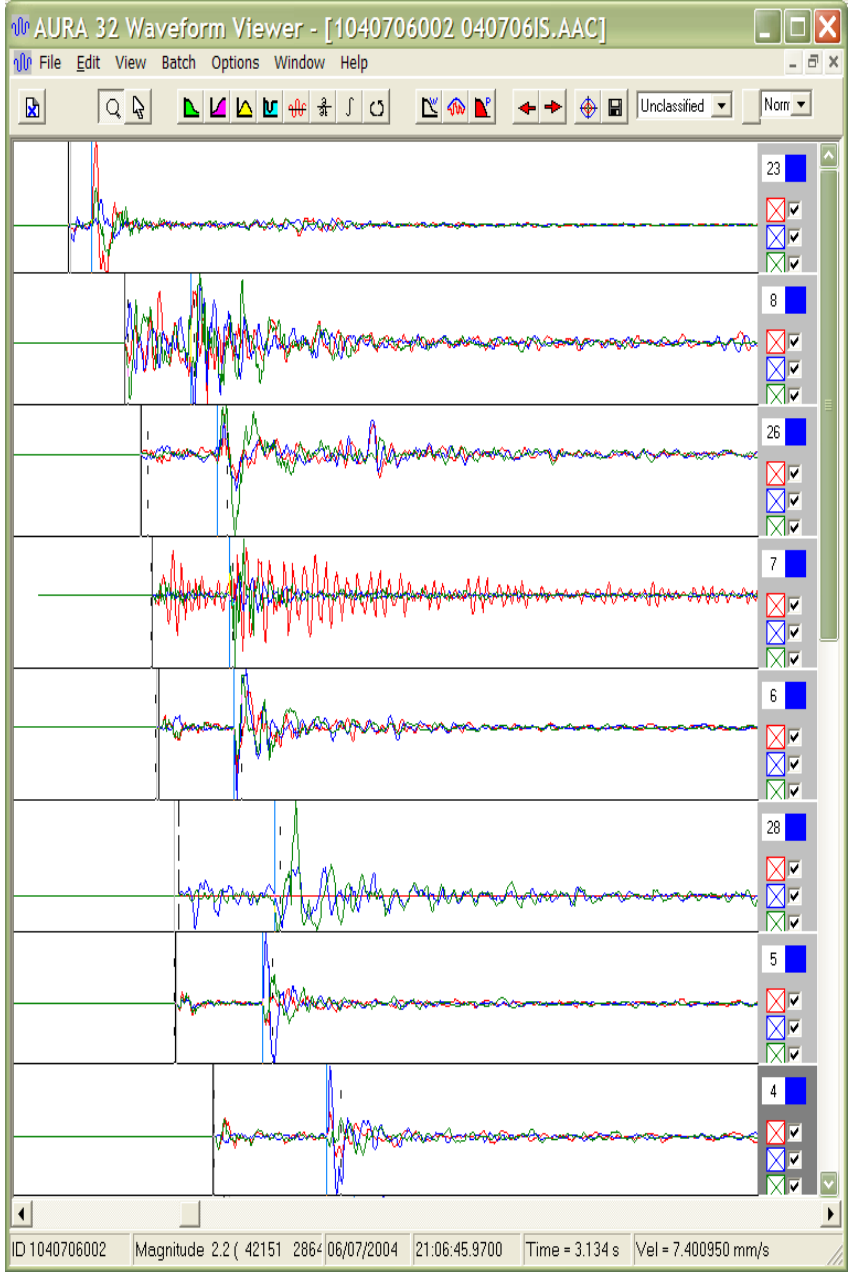
The process so far has been research-based, mining group- and supplier-driven in the development of sophisticated seismic monitoring systems, but no comprehensive seismic risk management plan (SRMP) has been introduced as a best practice guideline for the industry to analyse measured seismicity.

Most deep-level gold mines have adopted a seismic rating system and provide one or more ratings per working place/polygon daily as a form of warning of potentially hazardous or changing seismic conditions.

In general, the rating per workplace/polygon has been unsuccessful in terms of the “prediction of seismic events” and rock bursts, and at best can be used to compare current seismic responses to historic averages. Its efficiency should be quantified.

Reliable seismic data can assist in the overall understanding of seismicity and can guide prevention strategies, and, in the long run, perhaps facilitate forewarning of the occurrence of seismic events in space and time.

“This rating system has had limited success to date as a warning system.”



Research project

There are five phases in the scope of work, with the first two scoped in detail and the Phase 1 work allocated to researchers. Phase three will be finalised once the first two phases are completed, while the next two phases will be detailed once the earlier phases are concluded.

Phase 1 reviews current local and international seismic risk management practices and the development of a gap analysis.

Phase 2 will develop alternative machine learning methods to predict large seismic events and to rigorously test the models on data sets from three different mines with high seismic risk. After the evaluation, it is essential to determine whether the methods can reliably predict large seismic events in the short term.

If they can, practical recommendations must be proposed for risk management. If these events cannot be predicted, then the possibility of using the results for other indications of seismic hazard should be evaluated.

The findings on the accuracy of warnings should be analysed in the current scenario. If it is found that the warning concept is not achievable with current data, the focus should be on seismic risk prevention.

A review of the current seismic parameters used to quantify the seismic rating and associated warning needs to be revisited and evaluated, based on the historic findings of the rating system.

Alternatively, the integration of non-seismic parameters could also be evaluated to ascertain if their inclusion and further integration with other seismic measurements could improve the seismic rating and ultimately the warning of the onset of rock failure.

There is a prerequisite to have and use a state-of-the-art seismic system that allows for reliable seismic data, much of which is already available, to provide the knowledge and insights to improve applied rock engineering practice.

“If it is found that the warning concept is not achievable with current data, the focus should be on seismic risk prevention.”

Risk management

Reliable seismic data can assist in the overall understanding and can thus guide prevention strategies, and, in the long run, perhaps facilitate forewarning of the occurrence of seismic events in space and time.

The more detail regarding the location and seismic mechanisms of individual events is available, the more the understanding will improve that can assist with managing these various types of seismic event source mechanisms.

Any seismic warning information obtained by systems that assist in identifying higher-risk areas should be able to transfer the information to the area of concern in real time to ensure a timeous and appropriate response.

The review will deliver updated seismic parameters to assess seismic risk in working places, setting guidelines for seismic network requirements that are regarded as best practice based on the risk of the operation.

.It will also set guidelines for the use and implementation of seismic information into long- and medium-term mine designs.

It will make recommendations for the development of software to deliver a short-term seismic hazard assessment system that will give real-time warnings..