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KNOWLEDGE BASE SYSTEM ON PRECONDITIONING PRACTICES IN ROCKBURST PRONE GROUND CONDITIONS

Introduction

The gradual depletion of the natural resources has led to the extraction of precious metal at a great depth ranging from 1.6 km to 4.0 km from the earth surface. As a result most the South African Gold Mines are currently operating at a great depth in order to extract gold deposit. However, this great depth comes with several challenges that cannot be solving using traditional, conventional and numerical simulation. According to the annual accident statistics released by the Department of Mineral Resources [1] in South Africa, extensive contribution of fatalities in South African Gold Mines have resulted from rock related incidents. Although there is a rapid drop on rock related fatalities from 1950s to present (2018 to 2019), but the rock related fatalities are still reported at an alarmic rate. Nevertheless, majority of these events were noted to be related to so-called Rockburst. There has been several arguments concerning the actual definition of the so-called Rockburst, in which Kaiser et al. [2] defined it as a damage that took place at the vicinity of the excavations; this damage was indicated to occur in a sudden and violent manner which is associated with seismic events. However the damage can differ based properties the rock mass and properties of the seismic events, as well stresses revolving around the excavation. The definition has been supported or validated by several studies which includes; Cai and Kaiser [3], however Ortlepp [4] provided a slightly different approach, in which the author defined so-called Rockburst as seismic event that generate a violent and substantial damage at the vicinity of the mine excavation. Cai and Kaiser [3] contested that rockburst is understood to be allied with “*damage to the excavation or its support system*”, the authors further the argument by indicating that “*seismic event alone without causing damage is not rockburst*”. For argument sake, it is very complex to argue that the so-called Rockburst is simple defined as a damage to the excavation or its support only, suppose there is a Fall of Ground (FOG) due to gravity or disintegration of the wedge/s on the hangingwall, the excavation and support damages are still experienced, therefore, the question will be is that still called rockburst based on the suggestion or proposal by Cai and Kaiser? This study proposed that a rockburst can be simply defined as the sudden release of energy (seismic event) from the rockmass which damages the excavation or its support system (term support

Preconditioning techniques have been applied in rockburst prone mines around the world to redistribute the stress peak further into the solid region ahead of the mining face by eradicating the strain energy in the asperities of the mining-induced fractures. This paper reviewed the application of preconditioning practice, specifically in South African hard rock mines and outline gap knowledge revolving around this study. The study has shown that there are two types of preconditioning techniques (face perpendicular and parallel). Only face perpendicular preconditioning practice has been documented to have been successfully implemented in both conventional and fully mechanized gold mines. In this paper, it is maintained that although this technique has been reported to have been successfully implemented in many cases, there are still unanswered questions concerning this technique, therefore it is argued that this practice cannot be made an international practice before this gap knowledge are well addressed.

Keywords: Face perpendicular preconditioning, Face parallel preconditioning practice, Rockburst, Rock fracturing, Radial fractures, Rockburst, Seismic events.

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system is referred to both reinforcement and support system in this study). Additionally to the previous discussion, Ortlepp and Stacey [5] provided five classes of rockburst noted in South African Gold mines which includes; *Strainburst, Buckling, Pillar or face crush, Shear rupture and Fault-slip*. All this classes has been evidence in several recent studies [6] and are still considered to be a problematic issue faced by South African deep to ultra-deep gold mines.

Brummer [7] stated that preconditioning appears to be a viable technique for combating the “crush” type rockbursts and has been shown to be successful worldwide, in hard rock and coal mines. The conclusions made by the previous has correspond very well with the outcome from Ryder et al. [8] in which the authors commented that preconditioning is one of the major strategies for dealing with the rockburst hazard and they described it as an active engineering measure to modify or control the dynamic behaviour of the rock. The preconditioning research has attracted many scholars due to continuous reporting of rock related issue from the mining houses in South Africa. In supporting the previous statement, Toper [9] has conducted a study on “the effect of blasting on the rockmass for designing the most effective preconditioning blasts in deep-level gold mines”, the author proposed that the preconditioning technique is a rockburst control technique which is intended to alleviate the effects of potentially damaging seismic events on the excavation face areas, with special reference to face ejection type of rock bursts. Owing that, the previous author also commented that the practical difficulties and the cost are probably the main reasons that preconditioning is not used extensively in South African mines [9]. In principle, the preconditioning technique is intended to prevent the accumulation of strain energy ahead of the working face or, at least control the release of the strain energy. The gas

and shocks generated by a preconditioning blast within the fracture zone remobilized the rockmass blocks by shearing through rigidities that were causing any lock-ups [9]. Furthermore, Toper [9], Sengani et.al. [10]; Sengani [6] confirmed that, the strain energy release is facilitated by the stable sliding of rockmass blocks past one another, thus reducing the risk of face bursting during the production shift. The stress redistribution away from the working face, due to a well-executed preconditioning blast, provides a low-stress cushion ahead of the working face which is able to absorb energy from more distant seismic events [9]. In order to achieve the desired objectives, the preconditioning blast must create a zone of rock that is fractured but still capable of carrying considerable stress. Thus, the stress profile ahead of the face is smoothed, with the stress peak moved further away from the face. The creation of a destressed cushion of rock at the face helps to reduce the damage to the stope if a rockburst occurs at a distance from the stope face.

Background of Preconditioning Practice

Sengani [11] and Toper [9] have indicated that the formal research study on rockbursts in South African mines started in the year 1948. According to their studies, this formal research was initially given to the Council for Scientific and Industrial Research (CSIR) by the Central Mining-Rand Mines group. The above authors further the explanation by pointing that five year later, the sponsorship of the research project was then transferred to the Chamber of Mines of South Africa and this organization started to investigate all the rockburst incidents on behalf of all mining industry in South Africa. As the investigation continues, a clear relationship between mining variables and rockburst incidents was achieved from this large formal project and some of the successful results from the projects were documented in Hill [12] and Cook et al. [13]. Hill [14] indicated that the rapid increase in rockburst incidence was experienced or noted during mining of the faces at the vicinity any seismic geological structures. The previous study did not present extensive empirical results or sophisticated and detailed results due to the fact that the research was not yet fully matured and some of the data could not be acquired due to poor technology advancement. Therefore, the study that provides the art behind the concept of preconditioning practice was initial reported by Cook et.al. [13, 15]. Cook et al. [13] indicated that the concept of energy balance around the mining excavation was incorporated when developing rockburst control method and techniques during 90 s, in order to assess the risk of rockburst occurrence. Cook et.al. [13, 15] study proposed what is currently well-known as the Energy Release Rate (ERR). Immediately after the proposal of so-called ERRS, the concept was widely used for the assessment of rockburst potential. This concept was used to determine the energy available for rock bursting and the balance of the energy stored in the rock mass through simply calculations. These calculations were usually conducted based on the assumption that the rock mass behaviour is elastic.

On the other hand the elastic theory was used as the basis of the early attempts for the purpose of understanding the physical processes involved in rockburst mechanisms. Cook et al. [13] further their discussion by pointing out that “the rock mass behaviour inferred from the empirical data acquired from statistical analysis, seismic observations, and

rock property studies was not inconsistent with the assumption of elastic behaviour”. However, the elasticity theory pointed out that a large change in the gravitational energy of the rock mass must take place as a result of mining and half of this energy change must be released in either a non-violent dissipation or violence dissipation. In the former case, the released energy was transformed mainly into heat through friction and, in the latter case into kinetic energy [9]. Although the theory of elasticity provided a good approximation of the rate at which energy must be released, the rate at which energy can be consumed non-violently was estimated [13]. This rate of energy release was noted to depend on many factors, such as the properties of the rock, excavation dimensions and shape, maximum possible closure and depth of the mine surface. In every case where a fracture zone exists ahead of a face, energy must be consumed in the transition from elastic rock to fractured rock. Since a rockburst is a manifestation of violent energy release, it is necessary to examine the balance that must exist between the energy supply, storage, and dissipation.

Cook et al. [13] demonstrated that the incidence of rockbursts is virtually zero for excavations below a critical size. At small spans, the rate at which energy could be dissipated by crushing is greater than the rate at which energy is released [13]. The span at which the two rates become equal can be interpreted as the critical excavation size [9]. As the excavation is enlarged beyond this critical size, the amount of energy released per area mined increases rapidly with increasing span while the rate of dissipation remains almost constant [9]. Hence, the incidence of rock bursts rises rapidly. A decrease in the amount of maximum closure permitted reduces the amount of energy released per area mined, which results in a reduction in the rockburst hazard. Since the rate of energy released increases with depth, the rockburst hazard can be expected to be higher with increasing depth. If the excavation surrounds a small abutment the incidence of rock bursting can be very high. An increase of stoping width also increases the rockburst incidents. In each of the above situations, the incidents of rockbursts further increase with the proximity of dykes or faults. With respect to mining layout and sequence, Cook et al. [13] stated that the alternative methods of arriving at the identical configuration of mining results vary at different rates of energy release, while the total released energy is determined solely by the final configuration of mining, and the geometrical rate at which it is released is influenced by the manner in which this is approached.

Cook et al. [13] explained that the rate at which energy is released can be minimised by keeping the total energy change as small as possible and by adopting a method of mining that ensures the most uniform rate of energy release. Since the total energy released increases as a function of the total volume of closure, its magnitude can be reduced by restricting the volume of closure. The total volume of closure can be reduced by keeping the stoping width as small as possible. There is, however, a practical limit below which the stoping width cannot be reduced. Further reduction can only be achieved by either waste filling or by leaving solid supporting pillars. In order to achieve the most uniform rate of energy release, irregular face shapes, small abutments and remnants should be avoided. Cook et al. [13] also stated that the rockburst hazard can be reduced either by increasing the rate at which energy can be dissipated in a

non-violent manner or by reducing the rate at which energy is released. The study of rock bursts conducted by Cook et al. [13] showed that the problem can be viewed in two parts: that concerned with the region of continuous rock (assuming no geological discontinuities) remote from the excavation, in which the behaviour is assumed to be elastic and predictable; and that concerning the region between the elastic solid and the excavation, where the behaviour is non-elastic and inadequately formulated. The transition from the elastic to the non-elastic region involves fracturing and an associated release of energy.

Since the rockburst phenomenon has always been associated with rock fracture, it is necessary to examine more closely the mode of occurrence of fractures, the extent of the rock mass involved and the stress environment in which fracturing occurs. Simple visual examination and recording of underground manifestations of fracture commenced in 1953 [9, 13]. Characteristic patterns of rock fracture around the main excavations were identified. It was found that the dip of fractures in the hanging wall was general towards the face, whereas the footwall fractures dipped away from the face. While clean, inter-crystalline fractured surfaces did occur, it was common to find evidence of powdering or slicken siding suggestive of considerable normal stresses acting during movement along the fracture plane. Many mine officials claimed that these fractures, which they termed "burst fractures", occurred some distance ahead of the stope face and were direct evidence of the violent fracturing that caused some particular rockburst sometime before the fractures were revealed. Cook et al. [13, 15] indicated that with increasing distance from the plane of the reef, the frequency of fracture planes diminished but many fractures were still clearly evident in the post-developed footwall drives as far as 30 m below the stope. In the hanging wall, fractures were observed as high as 60 m above the stope. The width of the fractured zone ahead of the face was considered to influence the incidence of rockbursts markedly. However, due to the limited access available, it was not possible to determine the distance ahead of the advancing face at which fracturing became evident, or to suggest a definite shape for the fractured zone in the stope hanging wall and footwall.

Types of preconditioning practices

There are two different preconditioning techniques that have been developed previous, namely face-perpendicular preconditioning and face-parallel preconditioning. Both have prevented face bursting in areas to which they have been applied, even though several large seismic events have occurred close to the faces in some areas [16]. According to Rorke et al. [17], the face-parallel preconditioning has been studied since 1980s, however the first documented study was conducted at West Driefontein Gold mine. Meaningful experiments on this practice were conducted through drilling and blasting 76 mm diameter face parallel holes which were drilled up to 2.5 m and 3.5 m ahead of the mining face. It was also reported that 18 preconditioning holes were successfully drilled, as a result, the success of the method was evidenced by improvements on the hangingwall fracturing and little or less damage at the mining face after large seismic events. In those years, there was less instrumentation that could be used to validate the effectiveness of the methods, only the resultant ground conditions were used. In the year 1992, September, a second trial was reported to have taken place

at Blyvooruitzicht Gold Mine (BMG) in the 17–24 W stability pillar. This experiment was done due to the change in mining direction experienced at the mine, fortunately extensive monitoring was conducted at the site to have sufficient information for the purpose of taking appropriate geotechnical decisions revolving around the practice. Several improvements along the pillar were reported, it was noted that if the practice had not been done, a large seismic event might have been experienced [9, 16, 18]. However, this practice did not get to be accepted by other mines, since there were several questions about the validation of the method.

Four years later (30 January 1996), a large seismic event with the magnitude of 2.0 was reported and resulted into extensive damage along the stope gully, some of the panel were reported to remain unopened for sometimes [9]. As mining progressed, several seismic events of the same magnitude happened. In May 1996 the mine management team decided to abandon the entire panel affected and also stop the face parallel preconditioning practice since there was little information on how to validate the effectiveness of the practice [16, 18]. After this method stopped, the three and half years of data collected was then analysed by Lightfoot, et al. [19]. Therefore, a proposed study on the application of this practice was developed based on Kullmann, et al. [20] and Lightfoot, et al. [19, 21] study, the guidelines were then reviewed and further refined by Tooper, et al. [16]. Their guidelines were focusing on the drill, spacing and blasting of both preconditioning holes and productions. Eventually, a clearly schematic diagram was developed to ensure that the practice can be understood by both educated and uneducated miners and any production personnel (See Fig. 1, a).

In summary, the previous study [9] concluded that the method was found to be very effective and the method was found to easily transfer stress far away from the mining face, this was argued by pointing that the ground conditions were improved, and minor seismic events were reported during the period of the study. Lastly the previous study [9] also maintained that it could be very difficult to acquire equipment that could be used to drill such holes but the methods its self is best for pillar destressing. On the other hand, face-perpendicular preconditioning has been and still considered to produce very successful results and this method was also documented to be appropriate in long and narrow strike pillars. Historically, the experiment on face perpendicular preconditioning practice commenced in late 1957, one of the well know reported work was conducted by Roux et al. [22] at East Rand Proprietary Mines (ERPM) and also the work by Giltner [23] in which they propose the alternative way of applying preconditioning. There, the experiment decided to use short face perpendicular holes (about 3m drilled with 36mm diameter) throughout the mining stopes. Hill and Plewman [12] concluded that this alternative way was noted to improve the ground conditions and it was easily filtered within the production cycle. Due to the record made in 1957, the same practice was then revisited in 1994 as a new experiment at 87–49 W section of Mponeng gold mine but the face perpendicular commenced on the 23rd of May 1995, it commenced on the adjacent panels. As a result, this method was reported to reduce rockbursts incidences and a significant improvement in hangingwall conditions was reported. The design of the face perpendicular preconditioning was as shown in Fig. 1, b.

Fig. 1. (a) Face-parallel preconditioning layout in an overhand mining sequence (Modified after Toper, [9]), (b) Schematic view of fully drilled mining face with Four-face perpendicular preconditioned practice (Modified after Sengani and Zvarivadza [6])

Studies Reporting Successful use of The Preconditioning Practice

The study by Toper [9] compared the un-preconditioned and preconditioned blast on the mining panel. Toper [9] study has indicated that the preconditioned faces resulted in the improvement of face fracturing, transfer of stress from the mining faces, improvement of hanging wall conditions, a great improvement on the face advance, and a rapid decrease of rockburst occurrences. However, this work was conducted in conventional mines only. Therefore, this means that there was no information associated with the implementation of these methods in a mechanized gold mine. As mining progress towards deep to ultra-deep level, mechanizations was then considered to ensure safety and rapid extraction of the deposit. Although mechanization was considered, there was no specific destressing technique developed in order to ensure safety. The study by Sengani and Zvarivadza [6] was the first study on the development of preconditioning practice which is suitable for mechanized deep to ultra-deep level gold mining. Sengani and Zvarivadza [6] reviewed the preconditioning technique and developed the appropriate preconditioning practice in mechanized deep to ultra-deep gold mining. The study tested two types of preconditioning designs (Four and Five holes face-perpendicular preconditioning practices). Both techniques were almost the same, they only differ in the number of preconditioning holes and their spacing. The results of the studies have pointed out that five holes face perpendicular preconditioning practice was more effective and user friendly in mechanized mining. The results were supported by several studies such as [6, 10, 24]. Further results from the studies have shown that Five holes face-perpendicular preconditioning practice produce much more fractures ahead of the mining faces which reduce the occurrence of strain bursts, reduce the amount of fractures along the hangingwall and sidewall.

Furthermore, the study on the application of preconditioning practice in deep level gold mining in South Africa was conducted by Sengani and Amponsah-Dacosta [11], their study was on the application of long hole face-perpendicular preconditioning practice when de-stressing seismic active geological features (dyke). Their study commenced with an

extensive literature review on preconditioning practice, rock-burst, instrumentation and monitoring systems related to the effectiveness of preconditioning. Their major objective was to obtain an enhanced understanding of the face-perpendicular preconditioning practice when de-stressing geological structures that are far ahead of the mining faces [11]. Nevertheless, underground observations (visual examination), recordings and data collection were also conducted within the study area, which includes; the fracturing on the mining excavations before and after the practice. General ground conditions and photographs were taken after the observations. In order to understand the strength of the dyke and be estimating the stress levels, core logging was then used. Microseismic monitoring, Ground Penetrating Radar (GPR) and Borehole cameras were used for monitoring the effectiveness of the face-perpendicular preconditioning practice. Vantage software was used to simulate sigma 1 (major principal stress) ahead of the mining faces and in the vicinity of the dyke. MAP3D was used to simulate ride/displacement along the dyke and the results were used to estimate seismicity within the section. The results of the study have shown that the application of long-hole face-perpendicular preconditioning blast for de-stressing the Grey Ghost dyke was successful. The results were validated by the improvement in the hangingwall fracturing, sidewall fracturing and extensive fracturing on the mining faces after the implementation. A gradual decrease on recorded seismic activity ahead of the mining faces were also reported and the simulated ERR along the sections gradually decreases after de-stressing the dyke. Further results using MAP3D have shown that large seismic events were expected to take place during mining step five; in reality, those large seismic events were not encountered due to the implementation of the preconditioning practice. It was then concluded that the use of long-hole face-perpendicular preconditioning blasts successively de-stresses seismically active geological structures.

Development of fractures ahead of the preconditioned mining faces

Sengani and Zvarivadza [25] reported that Clotte et.al. [26] conducted the first study on fracture development ahead of the preconditioned mining faces and further validation of

these results were reported by Adams and Jager [27] the studies reported that the development of fractures ahead of an advancing stope face occur as a regular progression of new fractures forming ahead of the failed zone of rock mass ahead of the mining face. However, all these studies put more emphasis on the orientation and grouping of fractures ahead of the mining faces [6, 24]. The results of the study [27], have shown that there were zones of fractured and un-fractured rock ahead of the face, which were approximately 1m wide and continue as discrete entities approximately 12 m parallel to the face and 5m vertically. Further conclusions from their study have indicated that the zones of fracture do not form continuously as mining progress over a period of time.

After the above studies, there was no research work reported in South African gold mines concerning the development of fractures ahead of the preconditioned mining face. Therefore, Sengani and Zvarivadza [25] conducted a study on Borehole periscope observations of rock fracturing ahead of preconditioned mining faces in deep level gold mining. Sengani and Zvarivadza [25] studied the development of fractures ahead of the preconditioned mining faces through the application of several techniques which includes; application of the concept of core discs within the recovered core from the boreholes (14 m holes ahead from the mining faces, drilled at 90° and perpendicular to the mining faces), application of fracture characterization using both borehole camera and Ground Penetrating Radar with the use of fracture frequency table developed by Sengani and Zvarivadza [6] (See **Table**). This experiment was conducted within six section of a gold mine, the mine was mining at the depth of 3000 m from surface. The in-situ stress field of the mine were as follows; Major Principal stress (80.8 MPa), Intermediate principal stress (58.9 MPa) and Minor principal stress (36.3 MPa). According to their study [25], the purpose of the 14m holes was to inspect the development of fractures ahead of mining faces along several zone of undisturbed and disturbed and also monitor fracture development as time changes.

Based on the findings from the study, it was concluded that the development of fractures ahead of the preconditioned face occur over a period of time. Owing to that, the development of these fractures seems to be controlled by the rate of deformation within the mine, rate of mining, seismicity of the mine, the depth of mining as well as the strength of the surrounding rock. A further conclusion from their study has shown that fractures were grouped as zones ranging from 1 m to 1.5 m. These zones were reported to be separated by solid zones which were not constant in size. Besides that, the study also outlined that the core discs were much pronounced within a reef zone (conglomerate or gold-bearing rock) and rarely pronounced within quartzite.

The study also recommends that detailed investigations on the occurrence of core discs within conglomerate than quartzite need to be investigated. Due to that, it can be concluded that extensive fracturing should be observed from the borehole collar to a maximum borehole depth of 3m within the solid rock. After such a zone, a group of fractures is expected to be formed but these groups are separated by un-fractured solid ground. However, the intensity of fracturing tends to increase as mining progresses but not specifically within the same mining face and it might take time to occur based on the mining rate, ground conditions, depth of mining seismicity of the mine and rate of ground closure.

Standard for fracture frequency analysis (after Sengani and Zvarivadza, [6])

Fracture Frequency, metre	Risk Profile	Colour Coding
<5	High strainburst risk, rockmass not fractured/yielded	Red
5–10	Medium strainburst risk, rockmass beginning to fracture/yield	Yellow
10–20	Low strainburst risk, rockmass has fractured/yielded	Blue
>20	Very low strainburst risk, rockmass highly fractured/yielded	Green

Sengani and Zvarivadza [24] pointed that Kutter [28] study was indicated to be one of the first documented study on the provision of the completed the detailed understanding on rock blasting. Kutter [28] investigated the function of stress wave and gas pressure that take place during fracture generation with the use of an underground environment. Owing to that, he considered the action of the explosive to influence the generation of stress wave in the rock separately from that of the expanding combustion gases. Based on his experimental observation, he found that the main function of the stress wave is to generate a densely radially fractured zone around the borehole. He outlined that the gas pressure exerted against the walls of a highly fractured cavity generates a quasi-static stress field, the quasi-static stress field was modelled as a pressurized cylindrical equivalent cavity with a radius equal to that of the crack tips [6]. It was found that the quasi-static stress causes further extension of radial cracks, where the longest cracks would extend first and extension of two diametrically opposed radial cracks would be favoured. However, his studies did not consider gas flow and penetration into radial cracks. Due to the factor that [28] could not clearly state the mechanism of dynamic fracture formation, further laboratory experiments involving high speed photography and polymer have been used extensively to investigate mechanisms of dynamic fracture [6]. In 1970 high speed photography was implemented as to investigate the propagation of blasting induced fractures [29]. Person's [29] study has "found that two predominant crack systems which include, radial cracks initiated near the borehole or spalling cracks initiated as tensile fractures caused by the reflected stress wave" [6].

Sengani and Zvarivadza [24] provided clarity based on the orientation of radial fractures in the vicinity of preconditioned mining faces; their study was achieved through the analysis of the orientation of radial fractures in the vicinity of preconditioned holes. Two case studies were considered; mining face consisting of homogenous rock type (reef only) and mining face with multiple rock type (intersection of different reefs) dipping at 60° or less. The results from the study have shown that the orientation of radial fractures in the vicinity of effective face-perpendicular preconditioning holes was controlled by the geological discontinuities along the mining faces. Further results reveal that when a mining face consists of homogenous rock type, long radial fractures are expected to be formed in the direction of the major principal stress and short radial fractures in the minor principal stress direction (see **Fig. 2, a**). In

Fig. 2. (a) Long radial fractures along vertical axis and short fractures on the sidewalls of the preconditioned hole; (b) Long radial fracture along vertical axis and short fractures on the sidewalls of the preconditioned hole

a case where the mining face consists of bedding planes, long radial fractures were expected to form parallel to the dip of the bedding planes, with short radial fractures developed perpendicular to the bedding planes forming a spider wide structure (See **Fig. 2, b**). It was also noted that the short radial fractures at the vicinity of an effective face-perpendicular preconditioning holes were controlled by the distance between the boreholes, however when more boreholes were drilled and blasted closer to each other, more short fractures are developed and the size of that fracture relative to the original size of the borehole is determined by the following factors; the number of boreholes drilled and blasted, size of the excavation, amount of explosives used when blasting such holes, timing and tamping of the borehole, the strength of each rock layer, spacing between the boreholes. The results using numerical modeling has shown that a region of high clamping force is usually developed in an opposite direction of the major principal stress. Underground observations by Sengani and Zvarivadza [11] have also indicated that short radial fractures were more concentrated within this zone. The study concluded that the concentration of short radial fractures might be highly influenced by high clamping forces that tend to prevent gas from penetrating during blasting resulting in short blasting radial fractures being formed.

Discussions and Conclusions

The literature review revealed that there are several documented case studies on the application of preconditioning practice in South Africa, the literature review also revealed that there are a limited number of documented cases which clearly stated the preconditioning practice in mechanized deep to ultra-deep gold mines in South Africa. The PhD study conducted by Toper [9] is one of the current successful studies on the application of preconditioning practice in conventional mines. Toper [9] study provided positive results in preconditioning practice, but his results and experiments are only applicable in conventional mines. Owing to that, Sengani [11] study on face-perpendicular preconditioning practice in deep level gold mining, has shown that five face-perpendicular preconditioning holes are more effective as compared to four face perpendicular preconditioning holes. However, his study was focusing on the comparing of two face perpendicular preconditioning practices, therefore

there are several concepts that the study did not cover or did not provide answers for. Based on the available information, the study presented in this paper argue that there are several significant parts of precondition practice that are not yet investigated; therefore, some of the paramount parts of it are as follows.

It is crucial to put more effort on the understanding of the impact of face perpendicular preconditioning practice on local seismic activities, further study on the effect of face-perpendicular preconditioning practice on the intensely bedded or highly fractured hangingwall in mechanised/conventional deep level gold mining. It was also found significant to have a detailed investigation on the effect of face-perpendicular preconditioning on the hangingwall where there is no distinct parting interface between the reef and hangingwall, it is also maintained that the optimisation of the timing of the face-perpendicular preconditioning blasts for the most effective integration into production should be studied/ investigated. Furthermore, from all previous studies, it was also noted that the effect of face-perpendicular preconditioning practice when mining through precautionary zones is not studied. Furthermore, crucial studies on preconditioning are to further the investigation by Sengani and Zvarivadza [25] on how fractures are developed ahead of the preconditioned mining faces through different ground conditions, and also investigate the application of face perpendicular preconditioning techniques in developments ends/haulages in mechanised gold mining and provide detailed comparison with preconditioning practice in distress cuts. It is then argued that without detailed studies on the identified gap knowledge concerning preconditioning, the practice cannot be used as an international practice or approved to be used throughout the world.

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Conflict of Interest Statement

The author wishes to confirm that there are no known conflicts of interest associated with this publication, furthermore, there has been no financial support given to influence the outcome of this work.

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