found that the use of preconditioning also leads to an overall improvement in ground conditions in the stope, as it tends to result in a smoother hangingwall. This has additional safety implications, as the hangingwall is inherently more stable and allows for more effective support installation.

The currently proposed mechanism for preconditioning has been formulated from a combination of direct underground observation and various measurements of the behaviour of the rockmass surrounding the excavation. Numerical modelling and physical modelling of preconditioning blasting have also been used. It is thought that the re-mobilisation and extension of existing fractures lead to a *reduction in the stress acting* across the fractures and, thereby, reduce the stress levels on the face as a whole. Consequently, a buffer zone of destressed rock is created immediately ahead of the face. As the face itself is less stressed, it is less *likely to burst. The transmission* of seismic energy through the buffer zone from more distant larger events is also reduced and, hence, the likelihood of damage to the stope resulting from such events.

The practical implications of the reduced face stress include more efficient drilling and more efficient blasting, in terms of both increased face advance per blast and more consistent *fragmentation of the material* removed by the blast. The smoother hangingwall is related to the induced shearing on the reef-hangingwall parting, which facilitates better control of the stoping width. Reduced dilution of mined ore and reduction in *support requirements* obviously have favourable cost implications. The combination of a safer environment and an easier workload will inevitably lead to an improvement in the morale and attitude of the workforce.

Choosing the appropriate preconditioning method

It is important to note that preconditioning should not be seen as a remedy for all rock-related problems. One should not attempt to use preconditioning to deal with *an underground* condition that would be more adequately improved by changing the mining method or stope layout. Preconditioning is not a substitute for good mining practice. Appropriate standards consistent with the mining environment *should be used* and application of those standards must be ensured.

There are two preconditioning methods, which differ in application and in effectiveness. While it is thought that the preconditioning effect produced by the face-parallel method is superior, this advantage should be weighed against the potential disruption of the mining cycle. Each method has implications in terms of face configuration, gully positioning and support design. The mining layout should facilitate the use of preconditioning, while continuing to allow for efficient removal of ore and for effective support of the rockmass surrounding the excavation.

Face-perpendicular preconditioning

Face-perpendicular preconditioning is well suited to normal production faces, as it integrates very well into the mining cycle and so is unlikely to have a detrimental impact on production.

The preconditioning holes would typically be drilled to 3 m in length and spaced 3 m apart, although these figures would depend on local conditions. The support spacing and distance to face should ideally be sufficient to allow for the use of 3.2 m long drill-steels. Although concessions might be necessary in unusual circumstances (e.g. if backfill is installed very close to the face), these requirements have not been found to create major difficulties in practice and have not necessitated any compromise to the support system in the face area to date. If backfill is placed too close to the face, extension rods can be used to drill long preconditioning holes.

The preconditioning holes would be stemmed for a distance equal to the length of the production holes but not less than 1 m, to ensure that the energy from the explosion is contained within the hole and imparted to the surrounding rockmass. The preconditioning holes are blasted as an integral part of the production blast and timed to ensure that there is at least 1 m of burden for each preconditioning hole.

Face-parallel preconditioning

Face-parallel preconditioning is recommended for use in special areas, such as remnant or pillar extraction, as it is thought to be a more effective method for dealing with the exceptional stress environments encountered in these areas. Maintaining high production from these areas is likely to be less of a concern.

It should be possible to set up the drill rig, drill the preconditioning hole, charge and blast, all within a single shift, so as to minimise any disruption to the mining cycle. For this reason, while such factors as the air and water pressure at the site and the specific drilling characteristics of the rig used need to be considered, it is recommended that the lengths of the individual panel faces should not exceed 20 m. The preconditioning hole should be drilled for at least the length of the panel face, although it is recommended that it be extended somewhat into the next panel.

It is obviously necessary to be able to position the large drill rig so that the preconditioning hole can be drilled (typically, 5 m ahead of the panel face). Thus, the gullies from which the drilling is to be performed should be advanced sufficiently far ahead of the face to be preconditioned. This need to accommodate the rig also impacts on the lead-lag distance between adjacent panels. A lead-lag distance of 8 m was used without significant difficulty at one of the project sites.

The stemming of face-parallel preconditioning holes is a rather more complicated issue than is the case with face-perpendicular holes. In the latter case, the stemmed length is removed with the accompanying production blast while, in the case of face-parallel preconditioning, the rockmass in the vicinity of the stemming is not removed with the blast. The stemming needs to be sufficient to contain the explosion in the hole: the required stemming length depends on the hole length and diameter and on the degree of fracturing near the collar of the hole, but is typically about 5 m. This can result in a substantial region of effectively non-preconditioned rock adjacent to the stemmed portion of the preconditioning blast.

The preconditioning blast is initiated via two coupled detonators placed a short distance into the explosive. The preconditioning blast is manually set off and only after a successful detonation are adjacent panels to be connected for a production blast. Sequencing has a rather different interpretation here than is the case with face-perpendicular preconditioning: in the case of face-parallel preconditioning, it is important that the sequencing of adjacent panels is carefully considered. The lagging panel should always be preconditioned first, to avoid the scenario of having stress thrown back onto that panel by the preconditioning of the panel that is further ahead.

Implementing preconditioning

In this section, the instructor should deal with the practical considerations of carrying out the preconditioning in the underground environment. The positioning of the preconditioning hole(s), the size and length of hole to be drilled, the sequencing of preconditioning blasts, the charging and stemming of preconditioning holes, as well as the initiation of each preconditioning blast would all be explained in detail on surface and demonstrated in the underground environment.

Guidelines for the correct implementation

In this section the instructor will go through the detail information on the guidelines for the correct implementation of preconditioning. The guidelines for face-parallel and face-perpendicular preconditioning are given in sections 4.3 and 5.7 respectively.

The importance of correct application

It is essential that all persons involved in the application of preconditioning should be made aware of the importance of the correct application of preconditioning, and that failure to apply the method correctly could well result in undesired effects, to the extent of worsening the situation rather than alleviating the faceburst hazard. In the case of face-perpendicular preconditioning, all of the preconditioning holes must be drilled and blasted at the correct spacing, or "hard" patches of stressed rock could be generated in the face, which could burst into the working areas during the subsequent shift.

In the case of face-parallel preconditioning, the preconditioning hole must be positioned within the recommended limits of distance ahead of the face. If it is placed too close to the face, damage to the face could result; if it is placed too far ahead of the face, the blast will either have no effect or it might act to transfer stress back onto the face, rather than away from it. No production blast should be made in a panel where the face has reached the position of the previous preconditioning blast, as this would effectively be mining into non-preconditioned ground.

Assessing the effectiveness of preconditioning

While guidelines have been compiled for the application of each preconditioning method, it is important to note that the details presented in the guidelines are based on the careful, intensive study of preconditioning at only a few sites, and so should be regarded as starting points for the application of preconditioning in situations that differ markedly from those that were investigated during the development of the technique. Thus, it is important that individual mines should monitor the effectiveness of preconditioning at their specific sites and be prepared to change some of the parameters to suit their specific conditions, so as to optimise the effectiveness of preconditioning at each site.

For face-perpendicular preconditioning, the parameters to be optimised include: hole length, hole diameter and the spacing between adjacent holes. For face-parallel preconditioning, the parameters to be optimised include: face lengths of panels, lead-lag distances between adjacent panels, the distance ahead of the face that the preconditioning hole is placed and the diameter of the hole. In both cases, the parameters are inter-related and cannot be assessed and optimised in isolation; the goal is to optimise the preconditioning system at the site by varying the parameters so as to achieve effective preconditioning of the stope faces.

Tools available for making the assessment

Assessment tools that have been found to yield useful information during the development of the preconditioning technique include: underground observation, measurement of face advance and drilling rate, fragmentation assessment, fracture mapping and hangingwall profiling, convergence measurements and monitoring of seismicity, Ground Penetrating Radar profiling, as well as various measures of the state of stress at the face. Clearly, some of the tools require specialist training, while others are more readily accessible to non-specialists and can be used by shift bosses, miners and the stope crew.

Observation of underground conditions, if conducted in a discerning manner, is a simple but useful tool for assessing the effectiveness of preconditioning in a stope. Regular examination of the faces and hangingwall should reveal significant differences between conditions before and after the introduction of preconditioning. The face should be "softer" (easier to bar after blasting) and the hangingwall should be smoother after preconditioning has been in use for a period. Additionally, particularly when using face-parallel preconditioning, significant bulking of the face towards the excavation should accompany a successful preconditioning blast (this will be easier to observe if paint lines are placed on the face before the blast). Sophisticated photogrammetric techniques have been investigated in an attempt to quantify the bulking effect, but with limited success. Regular observation will allow for an evaluation of the continued effectiveness of preconditioning, as well.

With effective preconditioning, face advance rates should increase significantly compared with those before the introduction of preconditioning. These rates could be measured after each blast from fixed points in the stope (e.g. support elements or convergence stations) and the cumulative effect should be measurable on monthly survey plans. There should also be fewer (and shorter) production-hole sockets in the face after a blast when preconditioning is being used.

When preconditioned ground is drilled, the drilling rates should increase significantly compared with those before the introduction of preconditioning. At one of the project sites, where face-perpendicular preconditioning was being used, it was found that the total drilling time for preconditioning and production holes was less than that required for production drilling alone before the introduction of preconditioning.

The material coming off the face after a blast should be both more highly fragmented and more consistently fragmented when preconditioning is used. This has additional benefits in terms of easier cleaning of the stope face and fewer blockages of the tips and ore passes. This effect should be qualitatively discernible underground. It could be quantified by some more sophisticated means (e.g. a photographic technique), if required.

While it has been found that no new fracture sets are generated as a result of preconditioning, regular detailed fracture mapping should reveal that fractures with favourable orientations are enhanced and re-mobilised when preconditioning is used. While simple enough to be used by non-specialists, hangingwall profile measurements allow one to quantify the improvement in hangingwall conditions after the introduction of preconditioning.

Two assessment tools that have been found to have particular application in the context of face-parallel preconditioning are convergence measurements and the monitoring of seismicity from the site. While these tools can, in principle, be used in the assessment of face-perpendicular preconditioning as well, the size of the face-parallel preconditioning blast and its isolation from the production blast make it particularly amenable to analysis using these tools. Convergence data can be acquired fairly cheaply, but the acquisition of useful seismic data obviously presupposes the installation of an adequate seismic network.

Convergence measurements would typically be carried out by an observer on a daily basis; various continuous convergence measuring devices (e.g. clockwork closure meter) are also available and allow one to determine the instantaneous convergence at blasting time, which has been found to provide insight into the state of stress at the face. Once the site has been monitored for a while, it is possible to use the measured convergence to evaluate the effectiveness of a preconditioning blast.

In the context of face-parallel preconditioning, monitoring of the seismicity from the site facilitates the evaluation of the effectiveness of a preconditioning blast in several ways. The size (magnitude, seismic moment or seismic energy release) of the recorded blast event allows one to determine whether all of the explosive was set off successfully. Occasionally, the recorded event might be larger than expected, indicating that the blast simultaneously triggered additional strain-energy release from the rockmass through an actual seismic event. Of course, it is possible for the blast to trigger a larger seismic event separated in time from the blast. In this case, two separate events would be recorded by the seismic system. Stress transfer induced by the blast would be indicated by the migration of subsequent seismicity away from the preconditioned zone. Additionally, examination of seismic source parameters should show, for example, that stress drops for seismic events in the preconditioned zone are lower than those for events in adjacent regions of the rockmass. In the case of face-perpendicular preconditioning, the effects of the preconditioning are not as obvious in the seismic data and their identification requires a very sensitive seismic network with very good location accuracy.

Although it requires special equipment and interpretation by a trained specialist, Ground Penetrating Radar (GPR) profiling provides a very clear indication of the effects of preconditioning on the condition of the rockmass immediately ahead of the advancing stope faces. Changes in the intensity and extent of fracturing and increased separation of the fracture surfaces after a preconditioning blast should be visible in the processed GPR data. GPR scans can also be used to assess the maximum permissible separation of adjacent face-perpendicular preconditioning holes when introducing preconditioning to a new site.

In principle, direct measurement of the state of stress of the rockmass immediately ahead of the stope faces would be the ideal way to quantify the effectiveness of the preconditioning. Most of the tools commonly used for this purpose are not suited for use in fractured rock. A solid-inclusion instrument has been developed at CSIR / Miningtek, but is yet to be proved for routine use. Indirect measures, such as the change in aspect ratio of rigging holes in the face, are possible indicators of the state of stress. Changes have been found in such measures after the introduction of preconditioning.

APPENDIX D: AN EXAMPLE OF RISK ASSESSMENT ON PRECONDITIONING

Matrix to determine Risk Index

Index	Significance	Priority	More than 100 events per year	Between 100 and 10 events per year	Between 10 and 1 events per year	Between 1 event per year and 1 event in 10 years	Between 1 event in 10 years and 1 event in 100 years	Less than 1 event in 100 years
(28-48)	A	High	Probable events more than 100 per year	Probable events between 100 and 10 per year	Probable events between 10 and 1 per year	Probable events between 1 per year and 1 in 10 years	Probable events between 1 in 10 years and 1 in 100years	Probable events less than 1 in a 100 years
(16-27)	B	Medium						
(1-15)	C	Low						
Severity ↓		Frequency →	1	2	3	4	5	6
Multiple Fatalities > 6000 Shifts Lost		1	48	47	45	42	38	33
1 Fatality ± 6000 Shifts Lost		2	46	44	41	37	32	27
600 – 5999 Shifts Lost		3	43	40	36	31	26	21
60 – 599 Shifts Lost		4	39	35	30	25	20	15
6 – 59 Shifts Lost		5	34	29	24	19	14	10
1 – 5 Shifts Lost		6	28	23	18	13	9	6
No Time Loss		7	22	17	12	8	5	3
"Near" Miss		8	16	11	7	4	2	1

PRECONDITIONING – RISK ANALYSIS TABLES

Step	Hazard	Cause	Consequence	Existing Controls	Risk Index			Recommended controls
					S	P	R	
1. Mark the hole	1a) The preconditioning hole is marked too close to a socket.	Human factor, as the correct marking procedures/standards are not adhered to. Lack of training.	Personal injury if the rock drill operator drills the preconditioning hole into a misfire.	1. Mine Standards. 2. Legal requirements. 3. Trained and qualified miners.	2	2	44	1. On-the-job training & coaching by supervisors on the preconditioning methodology.
	1b) The preconditioning hole is marked on the face in front of support that has been installed close to the face, which will cause the rock drill operator to drill a misaligned hole.	Human factor, as the correct marking procedures/standards are not adhered to. Lack of training.	Reduce the effect of preconditioning and possibly result in stress concentrations.	1. Trained and qualified miners. 2. Research done on preconditioning. 3. Positive behaviour reinforcement.	2	3	41	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Additional training for the drilling of long preconditioning holes.
	1c) The preconditioning holes are marked too close to either the footwall or hangingwall.	Human factor, as the correct marking procedures/standards are not adhered to. *Lack of training.*	Damage the footwall or hangingwall.	1. Trained and qualified miners. 2. Trained and qualified rock drill operators. *3. Research done on* preconditioning. 4. Supervision.	2	3	41	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Special awareness programme (training, meetings, follow-ups and positive behaviour reinforcement).
2. Drill the hole	2a) The preconditioning hole/s are not drilled according to the recommended specifications which included, but is not restricted to, the following; direction, elevation and position.	Human factor, as the correct drilling procedures/standards are not adhered to. Lack of training.	Reduce the effect of preconditioning and possibly result in stress concentrations, as well as cause damage to the footwall and or hangingwall	1. Mine Standards. 2. Trained and qualified rock drill operators. 3. Supervision.	2	3	41	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Additional training for the drilling of long preconditioning holes should be given to all rock drill operators. 3. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).

Step	Hazard	Cause	Consequence	Existing Controls	Risk Index			Recommended controls
					S	P	R	
	2b) The preconditioning hole/s are not drilled to the specified length (short).	Human factor, as the correct drilling procedures/standards are not adhered to. Lack of training.	Reduce the effect of preconditioning and possibly result in stress concentrations.	1. Mine Standards. 2. Trained and qualified rock drill operators. 3. Supervision.	2	3	41	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Additional training for the drilling of long preconditioning holes should be given to all rock drill operators. 3. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).
	2c) Not all the marked preconditioning holes are drilled.	Human factor, as the correct drilling procedures/standards are not adhered to. Lack of training.	Reduce the effect of preconditioning and possibly result in stress concentrations.	1. Mine Standards. 2. Trained and qualified rock drill operators. 3. Supervision.	2	3	41	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Additional training for the drilling of long preconditioning holes should be given to all rock drill operators. 3. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).
	2d) The preconditioning hole/s are not drilled in the correct direction or drilled parallel to each other.	Human factor, as the correct drilling procedures/standards are not adhered to. Lack of training.	Reduce the effect of preconditioning and possibly result in stress concentrations.	1. Mine Standards. 2. Trained and qualified rock drill operators. 3. Supervision.	2	3	41	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Additional training for the drilling of long preconditioning holes should be given to all rock drill operators. 3. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).

PRECONDITIONING – RISK ANALYSIS TABLES

Step	Hazard	Cause	Consequence	Existing Controls	Risk Index			Recommended controls
					S	P	R	
	2e) Compensation for roof rolls is not taken.	Human factor, as the correct drilling procedures/standards are not adhered to. The roll is not timeously identified. Lack of training.	May cause damage to the footwall and/or hangingwall.	1. Mine Standards. 2. Trained and qualified rock drill operators. 3. Supervision.	2	3	41	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Additional training for the drilling of long preconditioning holes should be given to rock drill operators. 3. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).
3. Charge up	3a) The preconditioning hole/s are over charged with explosives.	Human factor as the correct charging up procedures/standards are not adhered to. Lack of training.	Cause blowouts and damage/fracture the rock as well as reduce the effect of preconditioning and possibly result in stress concentrations.	1. Mine Standards. 2. Trained and qualified Miners. 3. Supervision.	2	3	41	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).
	3a) The preconditioning hole/s are under charged with explosives.	Human factor as the correct charging up procedures/standards are not adhered to. Lack of training.	Reduce the effect of preconditioning and possibly result in stress concentrations.	1. Mine Standards. 2. Trained and qualified Miners. 3. Supervision.	2	3	41	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).
	3c) The primer is not placed in the incorrect position in the hole (the bottom of the hole).	Human factor as the correct charging up procedures/standards are not adhered to. Lack of training.	No effect on the preconditioning but will make the removal of any misfire more difficult.	1. Mine Standards. 2. Trained and qualified Miners. 3. Supervision.	2	5	32	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).

PRECONDITIONING – RISK ANALYSIS TABLES

Step	Hazard	Cause	Consequence	Existing Controls	Risk Index			Recommended controls
					S	P	R	
	3d) The same type of fuse for all production and preconditioning holes is not used.	Human factor as the correct charging up procedures/standards are not adhered to. Correct fuses are not available. Lack of training.	Out of sequence firing causing misfires. Reduce the effect of preconditioning and possibly result in stress concentrations.	1. Mine Standards. 2. Trained and qualified Miners. 3. Supervision.	2	5	32	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).
4. Stemming	4a. The preconditioning hole/s are not stemmed for 1 metre to the collar of the hole.	Human factor as the correct charging up procedures/standards are not adhered to. Lack of training.	Cause blowouts and damage/fracture the rock. Reduce the effect of preconditioning and possibly result in stress concentrations.	1. Mine Standards. 2. Trained and qualified Miners. 3. Supervision.	2	3	41	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).
	4b. Incorrect or poor quality stemming material is used to stem the preconditioning hole/s up to 1meter.	Human factor as the correct charging up procedures/standards are not adhered to. Lack of training.	Cause blowouts and damage/fracture the rock. Reduce the effect of preconditioning and possibly result in stress concentrations.	1. Mine Standards. 2. Trained and qualified Miners. 3. Supervision.	2	3	41	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).
5. Timing	5a) Preconditioning hole/s detonate before the production blast holes.	Human factors as the correct connecting up procedures/standards are not adhered to. Lack of training.	Cut-offs and out of sequence firing of the face holes. Reduce the effect of preconditioning and possibly result in stress concentrations.	1. Mine Standards. 2. Trained and qualified Miners. 3. Supervision.	2	3	41	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).
	5a) Preconditioning hole/s detonate out of sequence (late).	Human factors as the correct connecting up procedures/standards are not adhered to. Lack of training.	Out of sequence firing of the face holes as well as blowouts. Reduce the effect of preconditioning and possibly result in stress concentrations.	1. Mine Standards. 2. Trained and qualified Miners. 3. Supervision.	2	3	41	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).
6. Blast								

PRECONDITIONING – RISK ANALYSIS TABLES

Step	Hazard	Cause	Consequence	Existing Controls	Risk Index			Recommended controls
					S	P	R	
7. Post examination	7a) Post blast examination of the preconditioning hole/s is not done.	Lack of training.	Miner will not determine if the previous day's preconditioning was effective and if a problem did exist, no corrective action would be taken.	1. Mine Standards. 2. Trained and qualified Miners. 3. Supervision.	2	5	32	1. On-the-job training & coaching by supervisors on the preconditioning methodology. 2. Special awareness programme (training, meetings, follow-ups, and positive behaviour reinforcement).

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