Holing Underground – An Example of the Swiss-Cheese Model

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On the 5th February 2014, at 10:35am a 900mm diameter borehole was holed through from the surface into the underground workings at Kestrel Mine. At this time two people were in the vicinity of the hole-through location. The resultant flow of material from the bore hole, estimated at 75 cubic metres, discharged under considerable pressure. The two people in the vicinity of the hole-through received only very minor injuries.

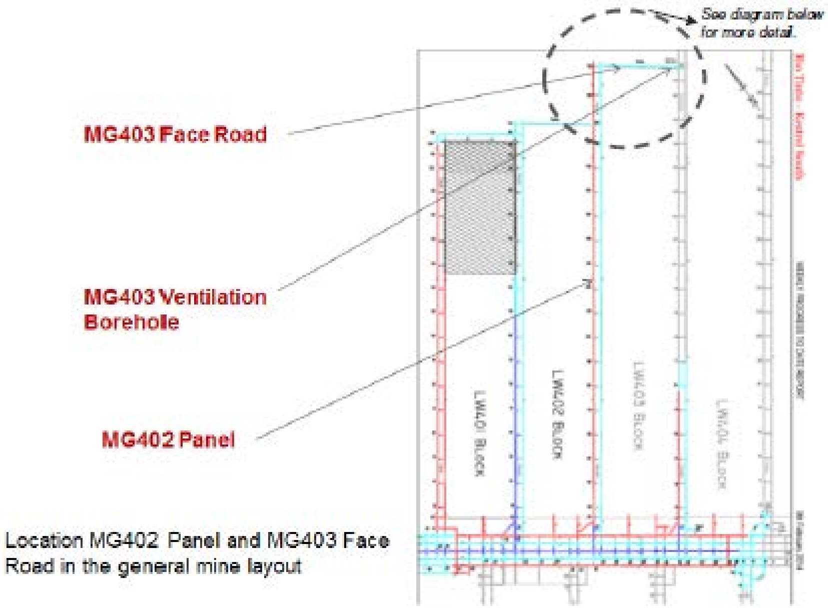
However, with all the focus on safety and critical risk management that goes into a modern coal mine, how did it come to pass that two people can be in the vicinity of a release of material such as this at the very moment it releases? This paper explores the aspects of change management, process execution and communications that can create an alignment of factors in the classic "Swiss cheese" manner. It also considers the effectiveness of controls and their interpretation by different individuals involved in a complex task at different stages.

This incident offers an opportunity to learn from doing an infrequent but not entirely unusual task and how subtle shifts along the path to conclusion can have a potentially serious outcome.

Introduction

Kestrel mine is located approximately 50km north of Emerald in the Lilyvale mining area of Central Queensland Highlands. It is an underground coal mine using longwall methods of extraction. The current mining location in the 400 Series of panels has been recently established in the Kestrel South location. The initial panels are approximately 2km long with a 375m wide face and that face width increases to 415m in the third (403) panel.

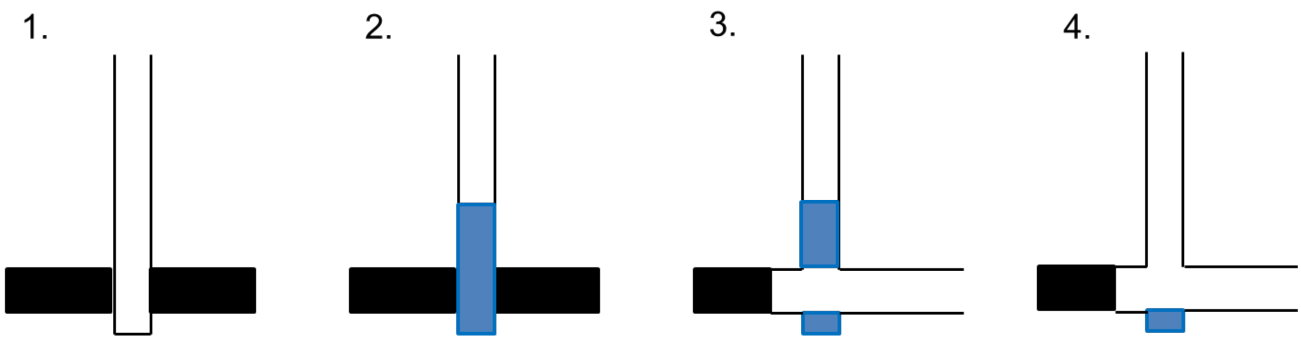
Figure 1 Faceroad and borehole location



It was determined the face road for the 403 panel would be developed as a single heading driven with a continuous miner. On reaching distance in the drive it was then determined the best way to continuously ventilate the heading was through the use of a 900mm borehole, thereby removing the requirement to apply forced ventilation into the heading. It was determined the 900mm diameter borehole would be used due to the efficiency advantages of a larger bore hole over the longer face, the reduced cost for a single-hole installation, the potential for the installed bore hole to have the capability as a rescue path and the availability, at the time, of a drill rig capable of drilling a hole this size.

The methodology for completing the ventilation circuit consisted of four steps; 1. drill the borehole to intersect the seam, 2. backfill the hole with grout, 3. intersect the grout-filled hole with the continuous miner, 4. then ream out the remaining grout to open the hole to the underground workings.

Figure 2 Borehole intersection methodology



Preparation

Having determined the method to drive the single entry faceline sometime earlier, as this work was well underway, and then resolving that a single large borehole would be used, the risk management steps for installing the borehole and connecting the ventilation were undertaken.

A first risk assessment was carried out on the 16th December 2013 to for the scope of the drilling activity and the interaction with the underground workings. This was a formal risk assessment process, facilitated by a competent person and undertaken by a team with a cross-section representative of the roles, skills and knowledge necessary to assess this task. The baseline for the risk assessment documentation was a previous risk assessment for installing ventilation holes in a single entry faceline at Kestrel North.

The drilling of the hole commenced on the 18th December.

A second risk assessment was conducted on the 7th January 2014, more specific to the interaction with the underground workings and the sequence in which activities were to be undertaken.

The incident investigation revealed that at this point the risk assessment process had not given due consideration to two aspects of this job that were different to the previous occasions for which the baseline risk assessment applied;

- A single 900mm diameter hole was being used instead of multiple 300mm diameter holes that have typically been drilled
- the typical sequence was to drill the holes after the after the heading has been developed

An increased hole diameter means the volume of the hole, any residual material in it and any associated hydrostatic head, will increase exponentially. The bailing pressure to remove cuttings and fluids also has to increase proportionately and reduced bailing efficiency experienced over the larger diameter makes it harder to completely clean out the hole. Missing the full implication of this aspect meant there was insufficient appreciation of energies associated with the discharge and release at the hole-through moment. Notwithstanding this, barriers were identified as a control in the risk assessment, however there was no specific detail provided on their construction, location and distance from the bottom of the hole.

Drilling the hole, grouting it and then mining through it increases the amount of interaction the underground processes have with the drilling processes and introduces complexity in these interactions. A procedure was identified as a necessary control for the interactions during the drilling activity. However, by not having considered the increased complexity in this case, this procedure was not prescriptive in sign-off, holdpoint and handover steps necessary for the next stage of the activity to commence in a controlled manner.

The drilling process

The bore hole was drilled without incident other than it missed its target depth to intercept the top of coal at 230m resulting in the hole being drilled to 259m. This increased depth opened up more open-hole section than was intended and resulted in more work for the bailing pressure to clear the hole. This increased the likelihood that fluid and cuttings were not flushed out and still in the hole.

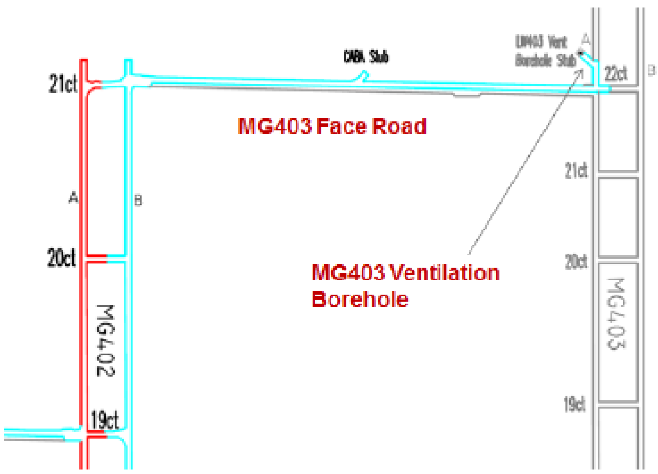
The hole was then cased to 230m and the grout was placed to backfill the hole. There were three separate grouting (cementing) jobs carried out before a 20m plug was established above the casing shoe. During the first job the grouting of the casing was completed, however the top of the plug in the bore-hole was well below the shoe. A second grouting job still failed to place the top of the plug at the intended depth, 20m above the casing shoe, resulting in the third attempt.

Up to this point nothing had been highlighted from either the initial risk assessment process or monitoring of the drilling to indicate there would be material of any concern remaining in the hole. On completion of the grouting the drilling activity ceased and the drillers demobilised, awaiting a call back to drill out the grout plug once the continuous miner had intersected the hole.

The reaming process

During the nightshift of the 3rd February 2014 the stub was driven to distance, intercepting the grouted hole.

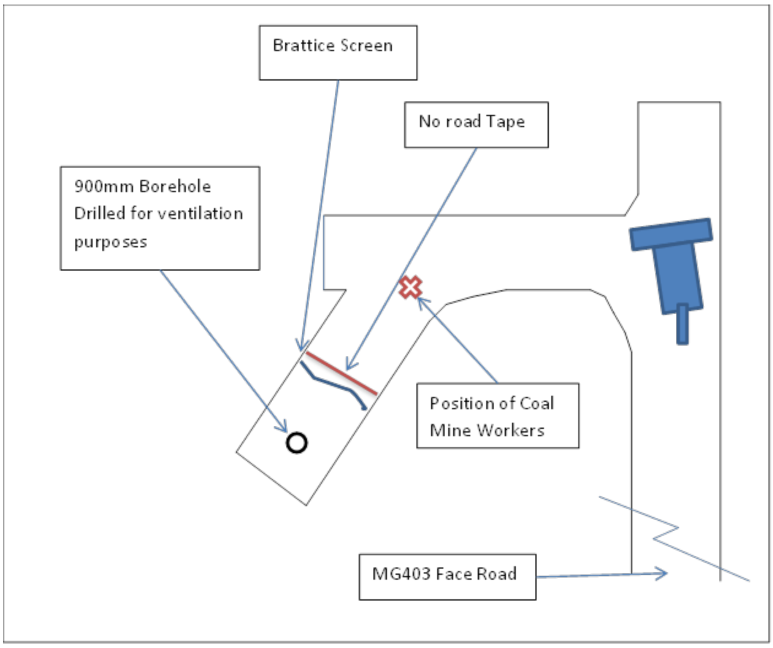
Figure 3 Borehole and stub location



It was now time to coordinate the hole through procedure. The job was being coordinated through the ventilation officer who briefed the control room operator (CRO) on the procedure specifically for this job. The Explosive Risk Zone Controller (ERZC) for the panel was informed the plan was to hole through; he was tasked with cutting the mesh off the roof section where the hole-through would occur and installing preparatory brattice ventilation stopping just out-bye of the hole. A length of no-road tape was installed on the out-bye ide of the stopping. At this time it was still believed that the hole would be empty, no other barricading or protection was installed to prevent entry to this area.

At 12:02pm, the ERZC notified the CRO the panel was clear as per the procedure and the drillers were informed they could commence drilling, which they did. Then at 12:49pm the drillers called to inform their drill string was blocked and they would need to clear it out. As a result the hole-through was not expected to occur on that day. During the following nightshift there was some incidental mining activity in the area and the continuous miner was moved out of the heading back to the face road.

Figure 4 Detail of stub and features



The morning of the 5th February

On the 5th February, on account of the site roster, a new crew commenced their tour. This introduced a new CRO and new panel ERZC into the procedure. This also proved to be a busy morning for the new ERZC with a General Manager State-of-the-Nation, pre-shift briefings and an array of personnel and operational matters to be dealt with. Amongst this high level of activity, the Ventilation Officer tried to brief the new CRO on the workings and status of the hole-through procedure. The CRO then passed on his understanding of the workings and status of the hole-through procedure to the new panel ERZC in a pre-shift meeting.

At approximately 9:05am, just as the ERZC was readying his crew to go underground in their vehicle, the CRO was asked to present for a random drug and alcohol test. While he was going to be at the test he asked a 'relief CRO' to fill in for him. Given the test would take only take ten or so minutes, there was no briefing on the intended drilling activity or hole-though procedure with the relief CRO. The drillers rang the control room at this moment, asking if it was ok to commence drilling. The relief CRO tried to obtain the necessary information for the drillers, asking the Development Coordinator, and in an informal exchange obtained an understanding that it was ok to commence drilling so passed this information on to the drillers.

The crew, the panel ERZC and the Development Coordinator then left to go underground with two misunderstandings; (i) the panel ERZC was not clear on his role in the next steps to progress the drilling work and only ascertained this while reading notes going into the mine (ii) they were not aware an inadvertent message had been passed on to the drillers that they could start drilling.

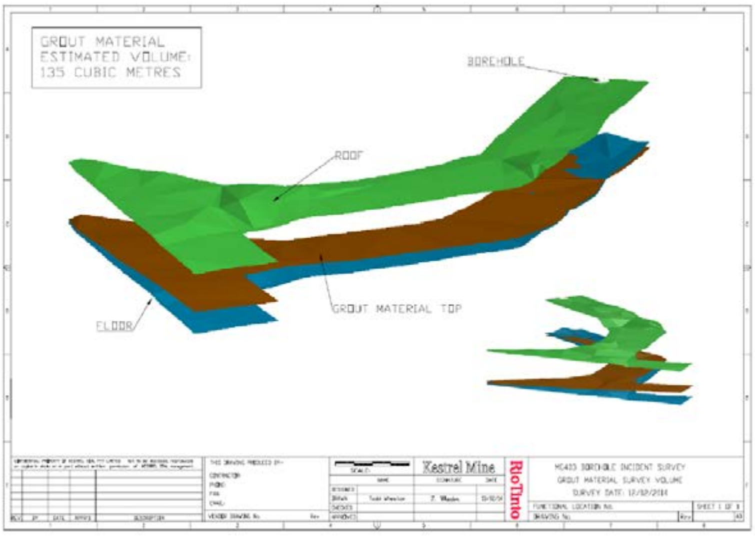
The incident

Once the crew arrived into the section at 10:10am, the panel ERZC's understanding, as far as he was concerned, was that no drilling was to start until he called from the panel to confirm that the area was clear of personnel. He asked a crew member to manage the daily panel prestart meeting and along with the Development Coordinator, proceeded into the face-road section for his inspection. At approximately 10:30am they inspected the area where the hole-through was to take place. They noted the brattice stopping and no road tape, looked behind it and noted where the hole through would take place. There was no sound or vibration to indicate, unbeknownst to them, that the drilling was already underway.

At approximately 10:35am the panel ERZC and the Development Coordinator had moved some 10-11m from the brattice when the hole-through occurred. At this time there was a release of fluidised grout cuttings and mud, pressurised from a considerable vertical head and the recirculation pressure. The panel ERZC and the Development Coordinator were struck by fine material (grout) and drilling fluid. They then made their way out to a communication DAC and called the CRO, who was able to inform them he had received a call from the drillers to say they had holed through.

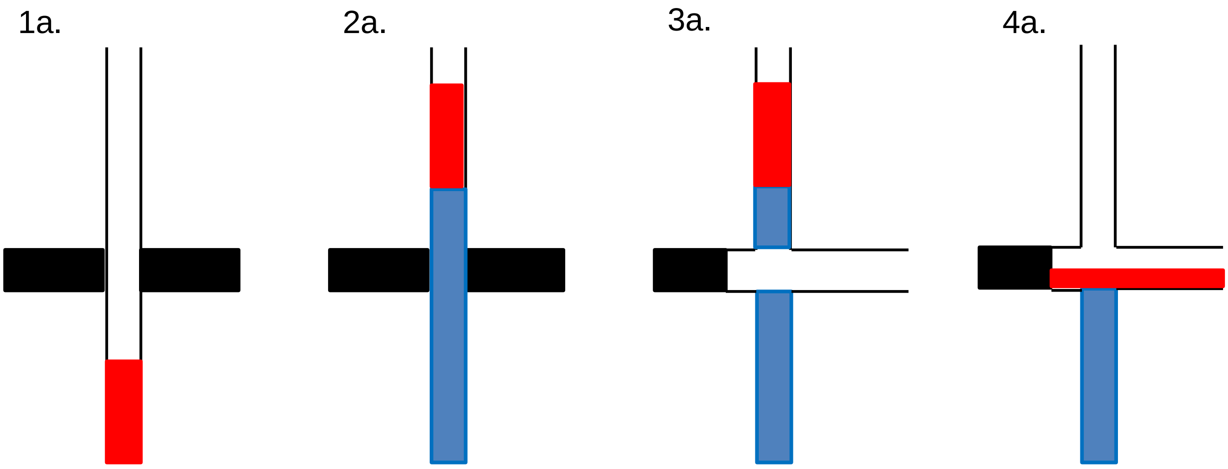
A subsequent survey of the area determined as much as 135 cubic metres of material might have discharged in the release. Considering a margin of error due to potential changes in the floor profile during the mining activity, it is estimated that there could be a variation of +/-44 cubic metres on this volume. In addition the volume of the drill string in the hole has to be accounted so it is believed the volume of the material in the hole to be approximately 75 cubic metres.

Figure 5 Survey detail of material volume



It was apparent now that the holing methodology looked more like that show in figure 6, steps 1a to 4a, with the red indicating the residual fluidised material in the hole.

Figure 6 Representation of borehole contents

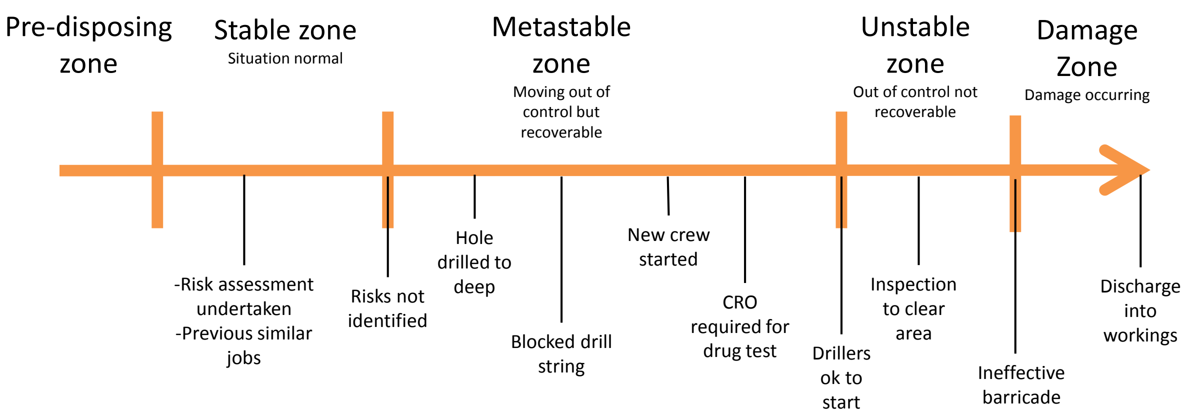


Increasing instability

The sequence of events and changes leading up to the moment the two individuals were exposed to the release of material into the underground workings provides an illustrative case study of how subtle changes and their lack of recognition accumulate and morph a job that is thought to be under control into a potentially serious exposure. This is often described as the Swiss-cheese model.

The increasingly unstable nature of the events as the incident moment approaches can also be represented in terms of the phase changes as per McDonald's time zone diagram. It shows that with each event a further defence is eroded, the opportunity to re-stabilise the changing situation diminishes and the situation changes from stable, where the situation is normal, to unstable, where things are now out of control and cannot be recovered.

Figure 7 Changing time zones and incident factors



The investigation carried out post this incident prescribed a number of actions concerned with addressing weaknesses in the risk management approach at for this task at Kestrel. Representing the key factors in a manner such as the" changing time zones" helps to "run the ruler" across the prescribed actions to gauge whether their implementation will prevent recurrence. Only one action preventing one of the factors is necessary to prevent recurrence.

What did we learn?

As a result of a detailed investigation into this incident, a number of corrective actions have been taken to reduce the risk of a reoccurrence:

- A formal Management of Change process has been established for one-off or new jobs, which involve concurrent activities (surface/UG, Cat 2, 3 Contractor groups). This process is applied, reviewed and signed-off, to ensure that the hazards and risks are understood and managed.

- A permit process has been established for activities involving interaction between a surface drilling operation and the underground workings. This requires formal sign-off by, as a minimum, the driller, CRO, Deputy responsible for the shift and a Dept. Leader.

Conclusion

An incident is described in terms of the factors leading up to it and the change management, process execution and communications are explored. The events and conditions leading up to an incident can create an alignment of factors in the classic “Swiss cheese” manner. These factors can also represent phase changes in the time prior to the incident and demonstrate how control of a situation can be diminished yet this deteriorating control can go un-noticed to the point that the situation is not recoverable.

Once identified, these factors can be used to test the likely effectiveness and quality of actions post an incident investigation, an action being effective if it prevents the factor materialising.