Abstract

The room-and-pillar mining method is well suited for continuous low and intermediate dipping narrow-vein deposits. However, major constraints arise with sudden dip changes and vein discontinuities.

In an effort to improve its productivity and safety records, the Sleeping Giant Mine, located in Canada and owned by Cambior Inc., is developing a working platform in conjunction with the adaptation of the long-wall mining method for its operation.

A first trial has identified deficiencies in the mining sequence, as well as in the platform design. A second phase was initiated, in collaboration with Natural Resources Canada, through CANMET Mining and Mineral Sciences Laboratories, to review the overall concept in order to achieve productivity and safety objectives.

This paper presents the current situation at the mine. It also provides a complete description of the innovative concept, which was developed, and a section is dedicated to the anticipated benefits. So far, the mine operator has completed a first stope trial and the main conclusions are presented. The results of this first trial served as the basis for the development of a second phase, during which the platform design and the mining sequence will be reviewed. The main objectives and expectations of that second phase are described. If proven, this innovative approach could serve in improving the performance of a number of narrow-vein operations.

1.0 Introduction

The Sleeping Giant Mine, located in Canada, is owned and operated by Cambior Inc. The main mining methods which it uses include conventional shrinkage and room-and-pillar. Whenever suitable to vein geometry and to ground conditions, long-hole methods are applied.

A large portion of its remaining reserves is located in sectors with sudden dip changes and vein discontinuities. The application of conventional mining methods in such conditions can lead to injuries and low performance. The miners are working on irregular surfaces and
material handling in the stope is physically demanding. In order to recuperate its remaining reserves safely and economically, the mine operator had to look at innovative alternatives.

A review of a number of mining approaches has demonstrated the potential gains that could result from the adaptation of the long-wall mining method, combined with an innovative working platform.

This paper presents the current situation at the mine. It also provides a complete description of the innovative concept, which was developed, and a section is dedicated to the anticipated benefits. So far, the mine operator has completed a first stope trial and the main conclusions are presented. The results of this first trial served as the basis for the development of a second phase, during which the platform design and the mining sequence will be reviewed. The main objectives and expectations of that second phase are described. If proven, this innovative approach could serve in improving the performance of a number of narrow-vein operations.

2.0 Current situation

The room-and-pillar mining method is currently used when the dip of the vein is less than 45 degrees. The mining sequence progresses from the bottom up and requires four (4) metres by four (4) metres rock pillars set at regular intervals in the stope. The ore is scraped down the stope as mining progresses. The method is safe and well suited for a continuous low dipping orebody.

However, a large portion of the mine’s remaining reserves is located in areas where the geological interpretation has identified severe dip changes and discontinuities in the vein. A section view of a typical stope profile is presented in Figure 1.
Using the room-and-pillar mining method in such conditions gives rise to several planning and operational problems. The main ones are listed below:

- difficulties in getting an accurate geological interpretation of the vein;
- hard to plan the work in advance;
- constant changes in engineering drawings and specifications;
- occasionally, the mining method has to be changed locally into a shrinkage method;
- low productivity;
- the ground has to remain stable until the stope is completely mined out;
- a large portion of the stope is mined as development (30%);
- frequent corrective excavation work is required to respond to dip changes;
- unstable and inclined working surfaces (Figure 2);
- frequent rehabilitation work is required.

This new reality called for a change in its mining practices in order to provide a safe and economic method for the mine’s future. For that reason, a working group was set up to analyze the problems and to provide recommendations to improve the situation. It concluded that the adaptation of the long-wall mining method, combined with the development of a working platform, could eliminate most of the current problems at the mine.
3.0 Description of the concept

The introduction of any new mining approach must be carefully evaluated in regard to its safety and economic potential. In this particular case, a mining method had to be adapted to suit particular vein geometry, a working platform had to be designed and, finally, the ground control procedure had to be entirely revised.

3.1 Mining method

The long-wall mining method is currently used for narrow-veins dipping below 25 degrees. The selected sequence for the current project consists in developing drifts to delineate the top and bottom levels of the stope. Once the stope geometry is clarified, a raise is excavated along the dip to connect the drifts. Mining can then progress from this raise by excavating 1.8-metre slices along the dip. Each slice is blasted, one small section at a time, starting from the bottom and progressing upwards. Once a slice is blasted, the ground support and drilling of the next slice is performed by proceeding downwards. All of the drilling and blasting work is performed from the working platform by following the face.
Access to the work place, or to the platform, is provided by means of a manway equipped with ladders. The manway is relocated closer to the face as mining progresses. By using support posts, a wooden wall is erected to protect the manway from mining activities. Special brackets (Figure 3) were designed to quickly fix the planks to the posts. These planks will then be recuperated and used in the next manway arrangement. Figure 4 illustrates the general arrangement of a typical stope.

The method allows concentrating all the activities in a vertical corridor along the dip of the vein, therefore limiting the area which must be kept fully secure. Also, by following such a sequence, the vein is always visible, thereby allowing to anticipate any changes in the vein and react accordingly.

Figure 3 – Illustration of a manway
Figure 4 – General arrangement of a typical stope

3.2 Working platform

The dip of the stopes generally found at the Sleeping Giant Mine are steeper and more irregular than those found in normal conditions. Consequently, the long-wall mining method was used and a working platform had to be designed to provide a safe working environment for the miners. This platform had to be flexible in order to be easily adaptable to the various stope geometry. The main criteria of the platform design were the following:

- had to be transported in the shaft with no dismantling;
- had to operate in stope heights ranging between 2 and 3 metres;
- had to operate in dips ranging between 20 and 65 degrees (Figure 6);
- had to be adapted for the drilling of 1.8-metre slices;
- the total length of the platform working floor, including the foldable sections, had to be wide enough to provide access to the face and the manway, without having to go over an open hole;
- had to be supported by means of a cable and a winch when traveling and by additional safety anchors during mining. These anchors will have to be drilled in the stope floor and spaced at 20-foot intervals.

Figure 5 illustrates the first design version of the prototype platform.
Figure 5 – Schematic of the prototype platform

Figure 6 – Schematic of the platform in operation
3.3 Ground control

One of the most important criteria for the economic justification of the method is the maximum longitudinal excavation length possible which has to be kept as an open stope. In the first trial, conservative values were selected and will be reviewed according to the data obtained from ground monitoring. These initial parameters are:

- stope length: 15 metres;
- length to support: 3 metres;
- post capacity: 400 kN (40 metric tonnes);
- post spacing: 2.2 m x 2.2 m;
- estimated convergence: 50 mm;
- standard support: 1.5 m steel rock bolts;
- bolt spacing: 1.2 m x 1.2 m.

In order to replace rock pillars, an artificial support is required. Because it is quick and simple to install, a combination of steel posts with Jackpots was selected. The Jackpots were developed in South Africa and are distributed in Canada by Ground Control (Sudbury) Ltd.

There is a big difference between the applications of this kind of support in Canada and in South Africa. In South Africa, the ground is allowed to cave once the work face has been advanced. This allows to reduce the ground stress in the working face. In the present case, the stability has to be maintained throughout the entire excavation of the stope. Therefore, the support must be strong enough to withstand the pressure from the rock mass.

Resulting ground pressure estimations were made, but some critical data is missing and uncertainties remain. In order to guarantee stope stability, it was decided to use 400 kN capacity posts. To be able to reach that capacity, the posts must be made out of metal or comprise an assembly of wooden posts. Steel tubes were selected because they can be extended to adjust to various stope heights, thereby avoiding to have to cut the supporting units in the stope.

3.4 Modifications to the specifications before the first trial

When the platform was delivered to the mine site, it had to be dismantled in two sections and, on each section, pieces of equipment had to be removed in order to clear a maximum height of 30 cm to fit in the cage.

Furthermore, during the preliminary tests, the selected steel posts could not withstand a 40-tonne pressure without being damaged, as originally planned. Therefore, the ground support for the first stope trial was changed to 20-cm diameter wooden posts, with a capacity of 25 metric tonnes on a grid of 1.8 m by 1.8 m.
4.0 Anticipated benefits

A number of benefits are anticipated with the application of the new concept, in comparison with the conventional room-and-pillar or shrinkage methods. The main ones are listed below:

- increase in performance from 11.5 to 22 tonnes per manshift;
- safer working environment;
- simple mining sequence, conducive to reducing on-site decisions which have to be made in the stope to accommodate changes in vein geometry;
- elimination of rock pillars;
- elimination of physical efforts required to carry the material to the workface;
- immediate ore recovery;
- 90% stope recovery;
- elimination of temporary working platforms;
- flexibility to respond to sudden changes in the dip of the vein;
- requires only a small portion of the stope to be maintained secure.

5.0 First trial conclusion and analysis

Unfortunately, all the anticipated benefits could not be achieved during the first trial. However, many factors which require improvements were identified. This section provides a summary of the main problems encountered during the trial period.

5.1 Unfavorable geological context

As mining progressed, the vein turned towards the hanging wall, thereby requiring extra excavation to keep following it. The stope ended up being approximately 3 metres high, making it very hard to install the posts as planned. The posts had to be replaced by cemented cable bolts, which take longer to install and require a curing time before any other blasting activities can resume.

The final stope floor had a steep inclination towards the raise. The platform, which was attached by a cable, kept slipping away from the workface.

Other operational difficulties were encountered in the upper part of the stope, where the dip ranged between 50 and 70 degrees. With such a steep dip, the posts had to be replaced by cemented cable bolts.

5.2 Prototype platform design deficiencies

As already mentioned, the initial plan was to move the platform up and down the stope, using a cable and a winch. The lateral displacement was meant to be achieved only once the platform reached the top of the stope in order to bring it closer to the face in preparation
for the mining of the next slice. As described in section 5.1, because of the lateral variations in the dip of the vein, the platform kept sliding away from the face. That situation was the object of many trial-and-error modifications during the first in-stope trial. Two options were implemented; the first one consisted in replacing the hoist at the back of the platform by a stronger one. The second option involved the installation of metal legs at an angle on two cylinders, which are normally used to push and level the platform vertically, to allow moving it laterally. The latter option did not prove to be as successful as expected because of the weakness of this particular system.

Another limitation had to do with the location of the working floor. With the current arrangement, it was not possible to perform the drilling and support of the top portion of the stope from the platform. In order to carry out the required work, a temporary wooden platform had to be built, giving rise to additional delays.

The canopy was designed to protect the worker from falling rock between the working face and the manway, taking into account a maximum slice thickness of 1.8 metres. As a result, the manway had to be moved laterally after each slice, hence another time-consuming activity.

The working floor of the platform consists of a fixed section with two flip-type sections and is entirely made out of steel. As a result, the sections are heavy and hard to open or close.

5.3 Mining sequence

The platform could not be pulled high enough in the upper part of the stope to prevent any damage from rock projections following a blast. Consequently, the platform had to be moved laterally to avoid rock projections. That operation involved the use of the anchor point which was installed for the mining of the previous slice at the top of the stope. That maneuver proved to be difficult in view of the fact that it had to be carried out under the catwalk.

The staff had to constantly respond to the numerous problems that arose throughout the trial period. That situation made it hard to establish an orderly sequence to be clearly communicated to all workers. That resulted in poor planning and an inadequate distribution of tasks between the workers.

6.0 Second phase – Optimization of the concept

There are three main tasks required in the optimization of the concept. The first one, which has already been completed, consists in modifying the platform. The second one will be to review the mining sequence. The third one will involve a 2-month trial period in order to hopefully prove the anticipated full potential resulting from this innovative concept.
6.1 Modifications to the platform

With the lessons learned in the first trial, the engineering plans of the prototype were revised in order to implement the required modifications. The main changes are described in this section and a drawing of the modified platform is presented in Figures 7 and 8.

To guarantee efficient displacements of the platform at all times, a system consisting of eight hydraulic cylinders was included. Four vertical cylinders were combined with four lateral expandable units to allow moving the platform laterally. These cylinders can be controlled individually to level or incline the platform, depending on the particular conditions.

In order to optimize all the required activities in the mining sequence, the safety anchors were eliminated and replaced by four hydraulic cylinders that can be extended to the back of the stope, as shown in Figure 9. This allows to quickly fasten the platform, thereby eliminating any risk of movement while working on the platform. Following all the modifications made to the platform, the resulting operating height now ranges between 2 to 2.5 meters.

The canopy was redesigned to include a 1.8-metre expandable section, activated by hydraulic cylinders (Figure 7), to facilitate the mining of two slices of ore before having to move the manway. With this extension, the workers are protected from falling rock, thereby allowing to reduce the time associated with manway dismantling and reconstruction. The canopy was also moved to the upper part of the platform and solidified to serve as a working floor for the top portion of the stope. Moving the canopy to the front of the platform will also provide more space for the workers and for material storage.

In an effort to reduce the weight of the expandable working floor, these sections will be changed from steel to aluminum.

An automatic hose reel will be added to facilitate the handling of the compressed air hose.
6.2 Revision of the mining sequence

Some of the modifications to the platform were specially made to improve the mining sequence. With the new canopy arrangement, less time will be required for manway construction because it will only have to be moved once for every two slices mined.

The flexibility of the new displacement system will make it easier to follow the vein. This improvement should reduce the risk of having to mine higher than necessary. It will therefore be possible to replace the required cemented cables by supporting posts which are much easier and faster to install.

With regard to stope planning, additional care will have to be taken in positioning the primary raise opening in order to carefully align it along the dip. Finally, comprehensible procedures will have to be developed and clearly communicated to mine workers.
Figure 8 – Schematic of the modified platform

Figure 9 – Platform with the cylinders in expansion
Conclusion

The variability and discontinuities in the vein at the Sleeping Giant Mine gave rise to a number of operational problems. With this project, the mine operator plans to improve its room-and-pillar productivity to 22 tonnes per manshift as well as its safety records.

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The adaptation of the long-wall mining method, combined with the development of a working platform, could eliminate most of its current problems.

Unfortunately, all the anticipated benefits could not be achieved during the first trial in view of the large variations in the dip and the lateral displacements of the vein in the selected stope. That situation posed some problems during the excavation of the primary raise opening because its direction was not perpendicular to the direction of the vein. However, weaknesses in the platform design were clearly identified and a second phase was initiated to optimize the concept.

As a result, many modifications were made to the platform. First, a lateral displacement system consisting of eight hydraulic cylinders, comprising four vertical cylinders as well as four lateral expandable and retractable units, facilitates platform displacements in the stope. Also, four hydraulic cylinders were added to tightly fasten the platform and provide the safety anchors required as a double safety system to prevent the platform from sliding. In order to optimize the mining sequence, an expandable section was added to the canopy. With that section, the worker can be protected from falling rock over a surface equivalent to two mined slices (3.6 metres). This allows moving the manway only once every two mined slices.

The canopy was also moved to the upper part of the platform and was reinforced in order to provide a working floor to mine the top portion of the stope.

All these modifications should provide the required optimization to achieve the expected performance. If the trials can demonstrate the full potential of this concept, this will benefit a number of narrow-vein mines faced with the same challenges. A future development of the platform can also be expected, e.g. adding fixed drilling equipment as a way of mechanizing conventional mining.