Stick and Pillar Support on Union Section, Rustenburg Platinum Mines

C. W. KORF
Manager Mining, Rustenburg Platinum Mines, Ltd., (Union Section)

1. GEOLOGICAL INFORMATION

1.1 Lithology

The rock types directly associated with the extraction of platinum metals at Union Section are the pyroxenites of the Merensky Reef horizon and anorthosites of the Bushveld Igneous Complex. Figure 1 indicates the stoping in relation to these rock types.

The reef is a fairly weak rock of uniaxial compressive strength of 83MPa due, mainly, to its pegmatoidal texture and compounded by the varying degrees of serpentinisation. It is capped by a chrome band of the order of 2 to 3cm in thickness. It is necessary to remove this for grade considerations, which means the hangingwall must, at all times, be penetrated. The hangingwall is a porphyritic felspathic pyroxenite with uniaxial compressive strength of 160MPa. It is fairly heavy, with a specific gravity of 3.3. The pyroxenite grades into a norite which, in turn, grades into more anorthosite-rich rocks up to the bottom contact of the Bastard Reef, where there is an important discontinuity.

1.2 Dykes and Faults

These increases from about 2 per cent by area in the northern portion of the mine up to 15 per cent in the south where they have detrimental effects on the hangingwall control.

1.3 Jointing

Jointing in the area is probably the result of the cooling-off of the complex. The joint planes dip between 35° and 90° and form varying patterns on strike and dip. Serpentinisation along the jointing is almost universal. The net result is the formation of hangingwall blocks varying in size and shape from several square centimetres to several square metres.

Where jointing is inclined it forms trianguloid blocks. To maintain maximum cohesion between blocks, it is extremely important to restrict any decrease in lateral constraints to a minimum. When lateral constraints are removed, the cohesion along the jointing is lost and supporting the blocks is of vital importance.
Fig. 1 – Stoping shown relative to rock strata sequence
1.4 Bastard Reef Parting Plane

The contact between the Bastard Reef and mottled anorthosite below it forms a relatively weak plane at which separation can occur once closure has commenced. This has been confirmed by diamond-drilling.

The position of this parting plane is used to determine the thickness of the beam to be supported. Armed with this information, it is simple to calculate possible loads resulting in failure at this contact and so determine the required stick support necessary in the stope.

2. History

2.1 Pack Support

In the past, all the stope support at Union Section consisted of 0.6m × 0.6m mat-packs, at a skin-to-skin spacing of 3m on dip and 2.4m on strike.

Serious problems were experienced where stoping advanced to a point 30 to 40m on both sides of the centre gully. Sudden failure of the beam frequently occurred at this stage, causing parting of the rock at the contact of the Bastard Reef. This “sitting down” of the immediate hangingwall of the stope normally caused the loss of production (of a minimum of 1½ weeks per stope) in at least three to four stopes per month. In an attempt to reduce these losses, it was decided to install a more rigid type of support in the form of 15 to 20cm-diameter sticks at 2m × 1.5m spacing, with strike pillars 1.5m × 3m on the down-dip side of strike gullies (Fig. 2).

3. Load Calculations

3.1 Stick and Pillar Support

3.1.1 Weight of hanging to be supported. Weight to be supported over a 2m strip of hanging, panel to be 35m long and 20m thick. (Distance between stope and the Bastard Reef.) (2m strip is distance of stick support apart.)

\[
2m \times 35m \times 20m \times 3,204 \text{ (S.G. of rock)}
\]

\[
= 4,486 \text{ tons.}
\]

3.1.2 Load supported by 1.5m × 1m pillar (actual pillars cut 3m × 1.5m).

Accepting a 50% crushing of pillar load:

\[
1.5 \times 1 \times 8,300 \times 0.5 \text{ (Compressive strength of rock) = 6,225 tons.}
\]

Theoretically, the pillar will support the full weight of the beam. Sticks are additional to the general support requirements.
3.1.3 Number of 200mm sticks required to support hanging:

\[
\frac{4486}{60} = 75 \text{ (60t/stick)}
\]

\[
\frac{35}{75} = 0.47m \times 2.0m = 0.94m^2
\]

Actually installed 1.5m \times 2.0m = 3.0m^2 per stick (31% of total load).

3.2 Standard Method of Support

In order to standardise, the decision was taken to install the sticks at 2m on strike and 1.5m on dip. This allowed free passage of the scraper scoop between the rows of sticks.


Basis – requirement for 1 \times 35m panel from centre gully to limit (2 625ca)

<table>
<thead>
<tr>
<th>Pillar Stick Support</th>
<th>Pack Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of sticks</td>
<td>= 848</td>
</tr>
<tr>
<td>Number of mats</td>
<td>= 390</td>
</tr>
<tr>
<td>Number of wedges</td>
<td>= 468</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>848 \times 4' \times 8'' sticks @ 49c</td>
<td>2 880 mats @ 95c = R415,52</td>
</tr>
<tr>
<td>390 \times 2' \times 2' \times 4'' mats @ 95c</td>
<td>3 456 wedges @ 11c = R370,50</td>
</tr>
<tr>
<td>468 wedges @ 11c</td>
<td>= R 51,48</td>
</tr>
<tr>
<td>Total Timber Cost</td>
<td>= R837,50</td>
</tr>
<tr>
<td>Cost/ka</td>
<td>= R 0,32</td>
</tr>
</tbody>
</table>

Saving of 87c per centare, or R2 284 per panel to be mined to limit. The pillars can be removed on a retreat system.

5. Advantages

5.1 Grade has improved dramatically as all areas can be effectively swept where previously many had to be abandoned.

5.2 Substantial saving in transport and installation labour is effected.

5.3 Due to decreased volume of timber in stopes, the fire hazard is considerably reduced.

5.4 Improved ventilation conditions prevail as a result of only having to seal the gaps between pillars.
5.5 Due to the very open nature of the back area with stick support, the standard of sweepings has improved.

6. SAFETY

With this method of stick support the hangingwall beam is being contained and stability maintained. No stope cavings have been experienced to date and the decrease in the number of local falls of hanging is significant.

Hangingwall conditions over the advance strike gullies have improved, resulting in a reduction of accidents at this most important intersection point.

7. CONCLUSION

7.1 It is by no means suggested that stick support is a new innovation, but the method applied to our needs at Union Section has proved very successful.

7.2 It can also be stated that no collapse of any stick support stope has occurred since the introduction of this method.

Introductory Remarks by the Author. It must be stated that this type of support is by no means new but, with certain modifications and the introduction of strike pillars, it has proved most successful.

As can be seen from Fig. 1 it is the parting plane on the Bastard Reef which causes the most concern, and associated with this there are numerous dykes, faults and jointing planes common to this area. It was found that the passive nature of the mat-pack support caused a failure of the beam and a parting of the rock at the contact of the Bastard Reef, resulting in production losses. In an attempt to reduce these losses, it was decided to install a more rigid type of support in the form of 15–20cm-diameter sticks at 2m × 1.5m spacing with strike pillars 1.5m × 3m on the down-dip side of the strike gullies (Fig. 2).

Load calculations were made and it was found that, theoretically, the pillar would support the full weight of the beam.

The cost saving between pack and stick support amounted to 87c per centare.

Advantages
1. Improved grade
2. Saving in transport and labour cost
3. Reduced fire hazard
4. Improved ventilation
5. Better supervision of back areas
Safety
1. Reduced fall-of-ground accidents
2. Improved hangingwall conditions over strike gullies
3. No collapse of any stick support stope since introduction.

Contributed Remarks by W. D. Ortlepp. Mr Korf's use of simple load calculations as a basis for the design of stope support is commendable in several respects. It recognises that support should be designed to perform a particular function and, at the same time, rejects the false logic of merely increasing the support density if the first guess has proved to be inadequate.

Although there is obvious merit in simplicity there is also real danger in over-simplification. It is the intention of this contribution to illustrate these dangers in a realistic and, hopefully, a constructive way.

Pillars
The fact that the working strength of the rock in the pillar is taken as one-sixth of the compressive strength of the material indicates an awareness of the well-known size effect. However, the possible existence of joints, particularly if these are serpentinised, can further reduce the strength of the pillar very considerably.

As an example, the case of a collapse in a chrome mine at 70m below surface is presented. The lateral extent of the collapsed pyroxenite hangingwall, indicated in Figure 1, was about 45m × 100m and its height is presumed to extend up to an upper chrome seam 10m above.

The distributed stress due to 10m of hangingwall is about 0.35MPa. At a nominal size of 3m × 3m, the 50 internal pillars represent almost one-tenth of the mined area. The average stress in the pillars due to the potential load of the 10m of hangingwall was thus 10 × 0.35MPa which is one-seventeenth of the compressive strength of the material in the pillars (60MPa). The photograph in Fig. 2 shows that the pillars did fail, sticks were broken and solid timber packs were severely compressed.

There is, however, a more important factor to consider in pillar design. Because the pillar is very stiff, the stress in it is not determined by the 10 or 20m height of hangingwall that it is desired to support. The behaviour of the pillar is determined by the elastic convergence of the surrounding mined-out area. This is a function of the regional geometry and the height of the superincumbent hangingwall right up to surface. In fact, such small internal pillars will probably act as crush pillars with an indeterminate but very much reduced effective strength. If pillars are to be used as regional support it is axiomatic that they must be designed to support the entire rock mass up to surface.

While such crushed pillars may have some support capability, it is probable that, by themselves, they will not be able to support a 20m height of hangingwall. In this case, the sticks will not be additional support as assumed by Mr Korf but are an integral part of the support system. It is thus necessary to examine more critically the capability of the sticks,
particularly since they — being the only uniformly distributed support — may be called upon to play the dominant role.

**Stick Support**

A close distribution of relatively stiff timber sticks is better suited, in principle, to support a slowly-converging, jointed hangingwall than soft packs. However, timber, even when loaded longitudinally, is subject to creep or load-shedding. According to data recently published by Blight, the yield stress of saligna under slow-loading conditions can be as little as 40 percent of the strength indicated in short-term tests. Thus 250kN (or 25 tons) would be a more appropriate design value for 200mm-diameter timber props. The determination of the actual support capability of sticks in low-convergence conditions is something which is urgently required.

Another example from the chrome mines will serve to illustrate this point. Saligna sticks of 125mm diameter were spaced at 1.6m × 1.6m. Conservatively accepting a working load of 180kN (18 tons) per stick, this density provided a support capability of 2.3m of hangingwall. Despite this, occasional collapses of up to 150m² in extent have occurred in the worked-out area where the fallen slab has invariably been only 1.2m thick, separating from above the leader chrome seam. It was possible to crawl around on top of one such collapsed slab underneath a completely smooth and intact hangingwall!

**Support at Shallow Depths**

To conclude, it must be understood that the problem of providing
support at shallow depths is, paradoxically, more difficult than under moderately deep conditions. The very low rate of convergence means that introduced support, being passive, is not compressed and therefore possesses very little support capability. For example, at 250m depth, Mr Korf's stopes would have converged 20mm just before "sitting down". After 20mm compression the reaction induced in a mat-pack is about 140kN (14 tons). At the spacing quoted, this would represent a support capability of 0.7m height of hangingwall.

In other words the packs, which were not capable of preventing separation across a weakness, say, 1m up just prior to the stope sitting down, are suddenly subjected to the dead-weight of 20m of hangingwall. Naturally, dramatic closure in excess of 50 per cent of stoping width will occur.

Because of its greater stiffness, the new system has better capability than 0.7m of hangingwall. According to the calculations in the paper it is ten times better, with a capability of about 7m of hangingwall. Even if allowance is made for creep effects, it would probably still be five times better than pack support. On the other hand, if the 20m separation did occur, the behaviour of the sticks would be far less stable than that of packs: buckling, toppling or skidding would result in complete closure.

The fact that collapses have not so far occurred, despite the inability of the new system to prevent separation at the 20m weakness, requires explanation. In the light of present, admittedly inadequate, knowledge this must be attributable to the fact that the combined effect of pillars and sticks (with the sticks playing the more important role) is sufficient to prevent the 20m-thick "beam" from breaking its back at existing spans. If spans are not limited by residual pillars, unpay zones, dykes etc., a very real danger exists that collapse will eventually occur and that it will be extensive and sudden.

**Contributed Remarks By C. S. Stott.** We would like to thank Mr Ortlepp for his contribution to Mr. Korf's paper, even though the "sting" in the tail places a somewhat large question mark over our support system.

This system was initially tried on a limited scale and later introduced throughout the whole mine. The results achieved over many months have proved it to be safer, more efficient and cheaper than our previous system.

The example quoted by Mr Ortlepp refers to a small block of ground, some 2,500ca (70m x 40m), in completely different rock and at a very shallow depth.

The total combined area stoped to date on this system at Union is in excess of 1.3 million centares, mined at varying depths between 100 and 700 metres below surface – the largest single area being 252 000ca, representing 1,270m on strike and 198m on dip. This block is at an average depth of 650m below surface.

It is not our intention to support the mined-out area for ever and back areas are sagging as sticks break. At about 200m behind the faces 90 per cent of the sticks are broken and the pillars are crushed. Sticks start
breaking within 50m of the face. Steady and uniform closure in the back areas is also evident.

Our falls-of-ground accidents in stopes have been reduced most satisfactorily since the introduction of this support system, and statistics are as follows:

<table>
<thead>
<tr>
<th>Time</th>
<th>Fatal</th>
<th>Reportable Accidents</th>
<th>Total Accidents</th>
<th>Total Shifts Lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>January – December, 1976</td>
<td>6</td>
<td>70</td>
<td>226</td>
<td>3,904</td>
</tr>
<tr>
<td>January – December, 1977</td>
<td>3</td>
<td>34</td>
<td>182</td>
<td>1,699</td>
</tr>
<tr>
<td>January – September, 1978</td>
<td>2</td>
<td>10</td>
<td>120</td>
<td>941</td>
</tr>
</tbody>
</table>

As stated by Mr Korf, the incidence of caved working faces has virtually disappeared. The old support system produced on average six to eight stopes for re-raising and opening up per month.

It would be interesting to hear from Mr Ortlepp at what stage we can expect the "extensive and sudden collapse" he has predicted, and also what support system he recommends which will give us the same or similar results.

Further Remarks by W. D. Ortlepp. It is very reassuring to read from Mr Stott's contributed remarks that the stick and pillar method used on Rustenburg Platinum Mines has been so successful. There appears to be little doubt that the method is well suited to the particular range of depths, mining geometries and geological circumstances that exist. In the original paper the geology was well described but no indication was given of the prevailing depth and spans.

There is no doubt that a full study of the Union Section experience can contribute a great deal to rock mechanics knowledge which, as I indicated in my contribution, is particularly inadequate in the area of shallow mining.

From Mr Stott's description of sticks breaking and pillars crushing it is clear that the pillars, while admirably doing their share to prevent strata separation 20m up, do not inhibit elastic convergence to any extent.

In other words, they are behaving as crush pillars or yielding pillars, as I suggested in my contribution, and not as support pillars, as implied in the original paper.

In the example given, the elastic convergence in a long stope of 198m span at a depth of 650m will be about 110mm at most and almost 80mm at a point 50m behind the face. Subjected to this strain, sticks must break and pillars crush - if they did not, there would be something seriously amiss. If the pillars had been large enough to reduce appreciably the convergence that should occur at a particular depth and span, a potentially dangerous situation would have existed. The "hang-up" would represent a store of potential energy that, depending on the post-failure characteristics of the pillars and the regional "stiffness" of the system, would be available to propagate a chain reaction of pillar failure and extensive collapse.
C. W. KORF

With the happy choice of pillar dimensions and with span limited to 200 m, it would appear that the mine has achieved a controlled, stable situation. In these circumstances I would not expect an extensive and sudden collapse but I would certainly not increase the distance between "barriers" either! It is possible that the horizontal stresses existing at these moderate depths are sufficient to clamp the joint planes and prevent large blocks from sliding as happens at really shallow depth.

The original contribution was not intended to criticise the mining method but to guard against misunderstanding which might follow from the conceptual error implicit in the design of the pillars. The design assumed some lesser duty for the pillars and ignored the fact that they necessarily behave in accordance with the load imposed by the full depth and prevailing geometry.

If such an approach were applied out of context, a dangerous situation might well result. When yielding pillars are used, the regional stability of the entire structure must be provided for in some way, usually by limiting the span between abutments or barriers.

Mr Korf's paper will, I think, prove to have been a most valuable contribution to the literature as it has stimulated a constructive and fruitful interaction between theory and practice. This, and the subsequent continued study which I hope it will promote, will substantially increase our understanding of strata behaviour in shallow tabular deposits in jointed igneous rock.

21st July 1978.