Winning paper: Analysis of strike gully stability at TauTona Mine

by J. Thompson* Paper written on project work carried out in partial fulfilment of B.Eng (Mining Engineering) degree

Synopsis

A study into the stability of strike gullies at TauTona mine was to be carried out. In reaching the conclusions to follow, a three-stage process was followed.

- A literature study as well as discussions with management and workers alike to gain their inputs and perceptions.
- An ESH Department survey into the history of transgression from proper mine standard in TauTona strike gullies. Unfortunately records were found to be scarce and obscure and the importance of better inter-departmental recordings cannot be stressed enough.
- An underground survey of 11 pre-selected gullies distributed in both the UCL and LCL reef horizons. This stage is to carry the greatest weight in the points to be brought forward in this report.

The process highlighted and ranked the following areas as the most critical role players in the deterioration of strike gullies:

- Poor blasting practice
- Sub-standard siding depth and lead-lags
- Split sets
- Off line gully development
- Adverse geological features.

The following has been suggested to the mine to help reduce strike gully instability.

- Where possible, maintain lead-lags below 7 m—else increase the siding depth to suit.
- Decrease the gully width standard to 1.2 m (especially in 'high risk areas').
- Discourage drillers from drilling side holes in gully face blast pattern. This will allow for time in which tendon support can be kept up to date.
- Ensure split sets are installed 1 m behind the gully face so as to prevent opening up of fractures.
- Utilize the centre split set in the 1:2:1 pattern to maintain the proper gully line.
- When adverse conditions prevail, it is necessary to apply a special support plan not only to the panel face, but also (just as importantly) to the gully as well. Shotcreting of the gully hanging is a suitable long-term consideration for providing the additional areal coverage needed.

List of Abbreviations

CL	Carbon Leader	M/O	Mine Overseer
UCL	Upper Carbon Leader	FOG	Fall of Ground
LCL	Lower Carbon Leader	H/W	Hanging Wall
ERR	Energy Release Rate	F/W	Foot Wall
WDL	Western Deep Levels	ESH	Environmental Safety and Health

Introduction

Strike gully stability in deep-level gold mining is easily taken for granted and the direct effects of instability are seldom noticeable enough to be considered a threat by the everyday mineworker. Continuous negligence of proper procedure and non-adherence to gully standards slowly builds up (mostly unnoticed at first) until finally great losses in production result. A sudden decrease in the integrity of the strike gully occurs and many production hours are lost in the repair of these gullies before work at the face can safely recommence. It is, after all, these gullies that serve as transport medium of both men and material to and from the working place. Before the use of backfill, the primary area of concern in which most injuries occurred was at the panel faces. Strike gullies were simply necessary in gaining access to the workings. It wasn't until the 1990s with the proper implementation of backfill as stope support, that the true threat of strike gully instability on mining became apparent. The profound increased in-face safety, brought by the backfilling technique, has resulted in the tendency towards a greater percentage of all mine rock-related injuries taking place within the strike gullies instead of at the face as was previously the case. It would thus not be correct to say that strike gully stability is a greater problem today than 20 years ago, but instead it is more a case of the improved face conditions focusing the present day concern more on the strike gullies which have not benefited as greatly from the implementation of backfill.

The ESH department survey and the need for better recordings

A literature survey on the adherence of

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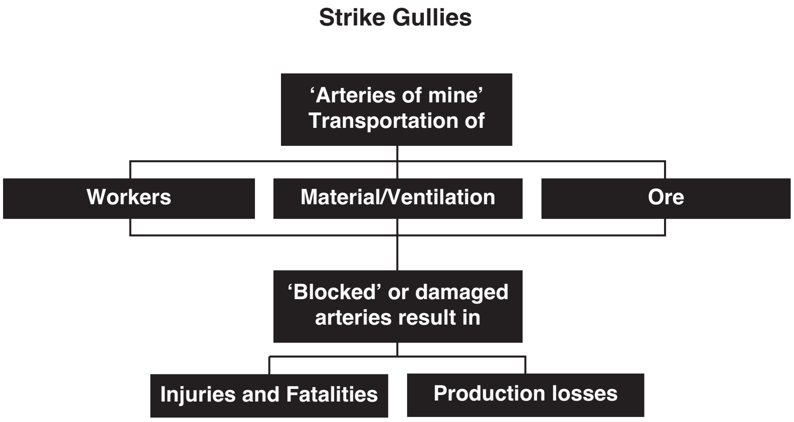


Figure 1—Chain of thought around importance of strike gully stability

selected underground sections to proper mine standard (concerning both gully support and stope layout) for the year 2000 was conducted. The source from which data was taken was the ESH Officer's Hazard / Sub-standard Conditions Report, from which all the strike gully related entries for the year 2000 were extracted. The descriptiveness of the data obtained was limited to the detail contained within these reports. In some instances the nature of the transgression was clear i.e. 'Split sets 6 m behind gully face'; yet often the entries were vague i.e. 'Bad, friable hanging in gully'—where the transgression responsible for the poor hanging is not stated and could have been due to any of the following:

- Too large a panel lead-lag or too small a siding depth being carried
- Insufficient or lack of barring down
- Poor blasting practice
- Too large an unsupported span (negligence of tendon support)
- and so on.

The performance of each section for the year 2000 is indicated by the amount of gully related entries for that section. Constant repetition of any one entry indicates sub-standard conditions in that section.

The data obtained through this survey did not clearly indicate anything substantial because the ESH records were obscure and difficult to interpret. The data in the ESH Officer's Hazard/Sub-standard Conditions Report could have been biased in the sense that certain workings may have been targeted and also, as mentioned, the data is often vague.

It was expected that conditions in the LCL would be extreme due to the high stresses at this depth and that conditions in the UCL should be substantially better. 83 occurrences of misconduct were found to be in the UCL vs. 77 occurrences in the LCL. This is not nearly large enough a difference to indicate anything at all. For this reason the creditworthiness of any data obtained from the ESH dept. survey was shadowed with great doubt. This is the reason why the underground observations made in the 11 selected strike gullies were necessary.

The importance of better interdepartmental communication and cooperation cannot be stressed enough and the creation of more descriptive records is a definite must. The implementation of a 'Fall-of-ground' campaign at TauTona hopes to address this issue in the future.

Details of underground workings visited

TauTona is mining both the UCL and LCL reef horizons. An equal distribution of strike gullies in both the UCL and LCL reef horizons were selected so that average, deep and ultra-deep parts of the mine were covered. To ensure the selected gullies were as representative as possible (to ensure that the selected gullies have a maximum number of factors in common so that they can be compared with one another) the study was limited to east advancing stopes only. The study was conducted over 3 weeks during the December 2000 break and thus a limited number of strike gullies could be visited. At the close of the vacation period a total of 11 strike gullies had been visited.

The following workings formed part of the study on the Carbon Leader:

		Depth below Datum
UCL	Section 321 Longwall 83/87	- 2550 m
	Section 325 Longwall 104/5 (Decline)	- 3140 m
LCL	Section 336 Longwall 104/106	
	Section 332 Longwall 118/120	- 3570 m

As far as possible, 3 strike gullies were visited per longwall:

- North side abutment (top of longwall)
- Longwall centre
- South side abutment (bottom of longwall).

For each gully, the following areas were concentrated on:

- Headings and panel lead-lags
- 10 m intervals along the full gully length.

Results of underground survey

Table I shows a summary of the recordings made during the underground survey. Appendix 1 provides greater detail.

Table I

Summary of underground surveyed results

	Description		PER CENT	PER CENT
	Adverse Geology (Includes adverse mining induced fracturing)		36	36
	Gully in poor or potentially poor cond. within 30m advance		82	82
	Two or more consecutive cases of flat fracturing		40	40
Transgression types/groups	Sidings	Average is sub-standard	86	78
	Sidings	Percentage of measurements sub standard (%)	70	
	Gully width	Average is sub-standard	50	45
	Gully width	Percentage of measurements sub standard (%)	40	
	Gully has history of long (> 10m) lead-lags		18	18
	Split sets	Further than 1m from gully face	90	77
	Split sets	Missing or incorrectly installed further back	64	
	Gully turns resulting in timber pack damage.		70	70
	Blasting malpractices (Only if noted…)		100	100
	Winch cubby - incorrect layout / lack of support		60	60
	Permanent support not to standard / not replaced		50	50
	Horizontal development of heading (currently)		50	50
	Gully is not clean (Can't walk upright) - Entire gully		100	100

Notes

- A gully is said to have **adverse geology** when abnormal geological features influence it. Thus a single joint set with nice steep extension fracturing or a minor fault is not deemed 'adverse', but an intersection of different joint sets and other sedimentary features (as found in Section 336) does. The 'adverse geology' column also refers to mining-induced fracturing which is orientated in a direction not expected, and is in addition to those fractures one would expect to find. This is typically the case in Section 332 (118 E3 escape gully) where strike-parallel extension fractures are present since the panel is mining a strike stability pillar.
- **Table 1** is only a summary of the underground observations and was drawn up specifically so that the observations made whilst underground could be interpreted and quantified.
- A certain type or group of transgression from mine standard is only considered applicable to a gully if it was noted to have occurred more than once.

Table II

Main strike gully instability role players

Ranking	ESH Dept. survey	Underground survey
1	*Bad hanging	*Poor blasting practice
2	**Incorrect use of split sets	***Strike gully not cleaned
3	***Strike gully not cleaned	*Sub-standard sidings and/ or lead-lags
4	****Timber packs undermined	**Incorrect use of split sets
5		****Gully turns (timber packs undermined)
6		*Adverse geology

(Entries that correlate are marked with the same number of asterisks).

Comparing these results with those from the ESH Department survey, we find that the main instability role players correspond with those from the ESH survey quite admirably (Table II).

The underground survey not only helped to verify the ranking of the main strike gully instability role players, but also helped to highlight the following points of interest.

82% of the gullies studied were in a poor condition within 30 m from the gully face

One of the objectives of the study was to comment on the time it takes before strike gullies begin to deteriorate. The gully should be safe along its entire length, but the primary area of concern is the sweeping line*. A sweeping line of 15 to 20 metres is a general figure and 30 m was chosen because readings were only taken every 10 metres and it adds a little cushion ensuring that the sweeping line falls within this region. Appendix 1 shows that nine of the eleven (82%) gullies studied were in a poor condition within the first 30 m.

An even more interesting point brought to light in Appendix 1 is shown in Figure 2. 67% of gullies in the LCL are mining under adverse geology and all of these gullies were in a poor condition within the first 30 m, the remaining 33% (not mining adverse geology) were less inclined to deteriorate as quickly. Surprisingly in the UCL, where no real adverse geology was found and ground stresses are less, 80% of the gullies were found to deteriorate quickly. Thus it could be argued that should adverse conditions not have existed in the LCL (as was the case in the UCL) then,

**The sweeping line of a mine defines a boundary line a certain distance behind the face within which sweepings are expected to take place. Here the mine is to ensure that all support aspects are safe and to standard.*

Appendix I

Summary of underground surveyed results

	Description		LCL						UCL							
			Sect 336			Sect 332			Sect 321			Sect 325		TOTAL	PERCENT	PERCENT
			106 E1	106 E3	104 E I	120 E2	118 E1	118 E3 (esc)	87 E1A	87 E2	83 E3 (esc)	105 E2	105 E4			
Transgression types/groups	Adverse Geology (Includes adverse natural occuring jointing and fracturing)		1	1	1	0	0	1	0	0	0	0	0	4	36	36
	Gully in poor or potentially poor cond. within 30m advance		1	1	1	0	1	1	1	1	0	1	1	9	82	82
	Two or more consecutive cases of flat fracturing		0	0	1	0	0	N/A	1	1	0	1	0	4	40	40
	Sidings	Average is sub-standard [1]	1	N/A	1	1	N/A	N/A	1	0	1	1	N/A	6	86	78
		Percentage of measurements sub standard [2]	50	N/A	100	67	N/A	N/A	100	0	100	75	N/A	70	70	
	Gully width	Average is sub-standard [1]	0	1	0	1	0	N/A	0	0	1	1	1	5	50	45
		Percentage of measurements sub standard [2]	17	45	38	50	27	N/A	15	25	100	44	43	40	40	
	Gully has history of long (> 10m) lead-lags		0	0	0	0	0	0	0	1	0	0	1	2	18	18
	Split sets	Further than 1m from gully face	1	1	1	1	1	N/A	1	1	1	1	0	9	90	77
		Missing or incorrectly installed further back	0	0	1	0	1	1	0	1	1	1	1	7	64	
	Gully turns resulting in timber pack damage.		0	0	0	1	1	N/A	1	1	1	1	1	7	70	70
	Blasting malpractices (Only if noted...)		1	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	1	1	4	100	100
	Winch cubby - incorrect layout / lack of support		0	1	0	1	0	N/A	1	1	0	1	1	6	60	60
	Permanent support not to standard / not replaced		0	0	0	0	1	N/A	1	1	1	1	0	5	50	50
	Horizontal development of heading (currently)		0	N/A	N/A	1	N/A	N/A	1	N/A	N/A	0	N/A	2	50	50
	Gully is not clean (Can't walk upright) - Entire gully		1	1	1	1	1	1	1	1	1	1	1	11	100	100
	Total Transgression		4	4	5	6	5	N/A	9	8	6	10	7			
	Percentage of possible 11 groups		36	36	45	55	45	N/A	82	73	55	91	64			
	Average over gullies		39			50			70			77				

0	- Not the case in the gully
1	- Noted as being the case in the gully
U / lined	- Borderline case (in general not far below standard)

1	Average of all measurements taken is below standard
2	Example: 2 of 10 gullies studied were sub-standard -

Notes:

- 82% of gullies studied, were in a deteriorated / poor state barely 30 m from the gully face.

- 67% of gullies in the LCL are mining under adverse conditions (geology or fracturing) - these gullies deteriorate within 30 m while the remaining 33% are less inclined to deteriorate as quickly.

- The gullies in the UCL are not as influenced by adverse conditions (Less hazardous) yet 80% of these gullies deteriorate quickly.

- The UCL is termed ‘less hazardous’ whilst the LCL is seen as being ‘more hazardous’ due to adverse geology and higher stresses.

- Flat extension fractures are almost exclusive (75%) to the UCL - sections 325 and 321.

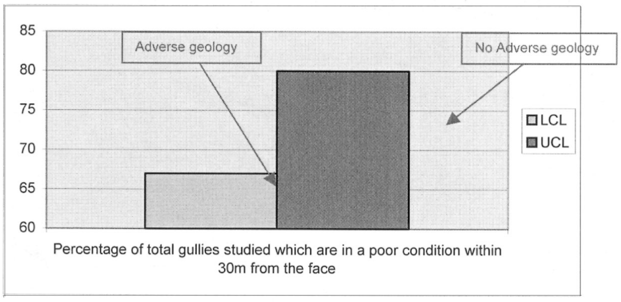


Figure 2—Percentage of gullies in a poor condition within 30 m from the face

possibly the LCL strike gullies would have all been in a good condition past the 30 m mark.

The only logical explanation was that this is a human related phenomenon:

> Workers in the UCL do not find themselves in as high a stressed area as those in the LCL, they are thus accustomed to the gullies being stable even when the proper mine standards are not adhered to. In the LCL the effects of not mining according to standard are quickly felt, the workers are more aware of the potential danger and thus are accustomed to doing things right.

There is a definite difference between the transgression in gullies in the Upper Carbon Leader (Sections 321 and 125) and those in the Lower Carbon Leader (Sections 336 and 332)

Figure 3. holds the second piece of evidence to support the phenomenon referred to above.

In the Upper Carbon Leader:

- 74% of the tabulated transgression groups take place
- Not as deep nor as influenced by 'adverse' geology or high stress as is the LCL (thus is a 'less hazardous' area)
- Greater tendency of non-adherence to proper mining standard
- Early gully deterioration in most cases due to these transgressions.

In the Lower Carbon Leader

- Only 45% of the tabulated transgression groups take place
- This is a 'more hazardous'* area due to ultra depth as well as 'adverse' conditions
- Early gully deterioration most likely more as a result of the adverse geology than transgression

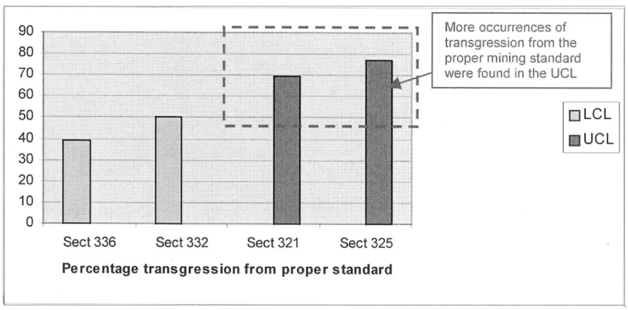


Figure 3—Recorded sectional transgression from mine standard

In many instances a gully width of <1.2 m was measured

This reduced gully width in no way limited the scraper operations and gully conditions where greatly improved in these areas. It is possible that this could be a contributing reason why gully conditions in the UCL are not as poor as expected (considering the high occurrence of transgression from standards in these areas).

It is thus suggested that TauTona attempt to reduce the current standard from 1.6 m to 1.2 m. A reduction in the size of any unsupported span holds only advantages for stability provided that movement within the workings is not negatively affected. It should also be noted that reducing the gully width requires our gullies to remain on line and straight.

Apparent relationship between siding depth and panel lead-lag

There appears to be a relationship between siding depth and panel lead-lag. When the panel lead lag is well below 10 m (7 m or less), a siding depth of 4 m is more than adequate. Yet a gully with a panel lead-lag above 7 m can be characterized with flat hanging fractures even if a siding depth in excess of 4 m is carried.

(Diering, 1987) suggested a siding depth of 6 m with a lead-lag confined to 15 m. The results of the observations made at TauTona tend to indicate that a lead-lag confined to 7 m is suited to a 4 m siding depth. A >7 m lead-lag was at times seen to produce flat fracturing even with a 4 m siding. (Güler, Dede *et al.* 1999) supported the 7 m lead-lag by referring to the majority of lead-lags studied being confined to 7 m. Using this as a basis, an estimate of the relationship can be made by interpolating linearly between these two points. It is unlikely that this relationship will be linear and it is suggested that additional research is necessary to properly define this relationship.

**Theoretically more problematic due to increased stress and depth.*

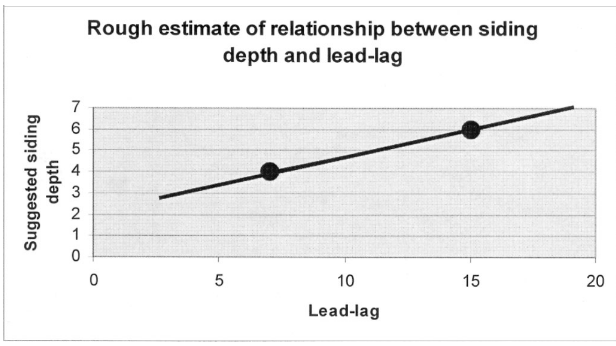


Figure 4—Estimation of the relationship between lead-lag and siding depth

Figure 4. suggests that the TauTona standard of <10 m lead-lags may require the required siding depth to be increased to roughly 5 m. However, Figure 4 is not based on substantial evidence and thus it is enough to suggest that for a siding of 4 m a lead-lag <7 m should be carried, else the siding depth is to be adjusted accordingly.

Discussion on the main instability role players

This section will discuss the main instability role players identified in the former section and will mention the suggestions put forward to the mine so as to help decrease strike gully instability.

Adverse geological conditions

Section 336 is a perfect example of what is meant by 'adverse' geological conditions.

A 'criss-cross' fracture/jointing pattern is evident in the hangingwall.

This is believed to be partially due to the reduced middling (between reef and Green Bar) of this area. It was also noted that the reef was carried low down in the panel face, thus effectively reducing the already below average middling even further.

The result is that 'key blocks' fall out of the hanging. Once a key block has fallen, horizontal-clamping forces in the hanging can no longer be maintained and the failure propagates outward over the entire hangingwall. The failure usually begins in the siding or 'stick-side' area and then propagates out towards the gully hanging.

Keeping in mind that section 336 is in the LCL, where non-adherence to mine standards are minimal, it can be said that if the mine can prevent these 'key blocks' from falling out, then hangingwall failure in the strike gullies can be largely avoided. In order to do this additional areal coverage is essential.

Very often, when adverse ground conditions are intercepted, special support layouts are only drawn up for the panel faces. Additional areal support coverage within the gullies as well, is critical to the safe passage through adversely conditioned ground.

Photograph 1—Adverse geology—'Criss-cross' fracture pattern in gully hanging

Photograph 2—Adverse geology—typical 'key block' failure in gully hanging

A few possibilities exist for the addition of areal coverage (Daehnke, Anderson *et al.* 1999). Super-skins similar to shotcrete in haulages (Evermine) are looking to be most useful in narrow tabular stopes. Other possibilities include mesh and lacing, an inflatable bag system still in a development stage at the CSIR, cable systems and rock consolidation techniques. Mesh and lacing in the stopes prove to be time consuming and very awkward; cable systems are inefficient in resisting relatively large vertical forces; the inflatable, reusable bag has not yet proven itself and rock consolidation has been tried unsuccessfully at TauTona already. Evermine has also been tried at TauTona and proved to be onerous thus, at the time of this study; shotcrete appeared the most promising avenue.

Applying shotcrete to the gully hanging seems to be the most logical solution and will most certainly prevent this key block initiated hanging failure. TauTona is currently investigating the use of various skins to provide areal coverage in gullies.

Another possibility, which is successfully implemented at neighbouring mine Savuka, is the application of backfill in the stick side. This will certainly prevent the initial key block failure in the siding from propagating into the strike gully, but holds both advantages and disadvantages over the shotcrete system.

These methods should be reserved for gullies where adherence to mine standard alone, is not enough to ensure a stable gully hanging. Special attention should be paid to siding area between the timber packs and the backfill since this is the area from which the failure initiates.

Poor blasting practice

With the help of African Explosives Limited (AEL)—Deelkraal Office, a blasting practice survey was done at TauTona. This survey showed that a large portion of strike gullies are not being marked, drilled and charged up correctly.

The area of greatest concern is the drilling and charging up of blast holes near the gully sidewalls. The drilling of

Table III

Comparison of backfill vs. shotcrete as a means of additional areal support

Backfilling stick side		Shotcreting gully hanging wall	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Equipment necessary is already present in the stopes and workers are currently practiced in the use thereof.	The stick side will no longer be available for the storage of equipment and the refuge of workers	Stick side remains open	Capital cost of the purchase of specialised equipment for use in stopes.
Effectively increased areal coverage	Water and air hoses will need to be carried in the strike gully	Effectively increased areal coverage	Worker to be trained in the application of the new system

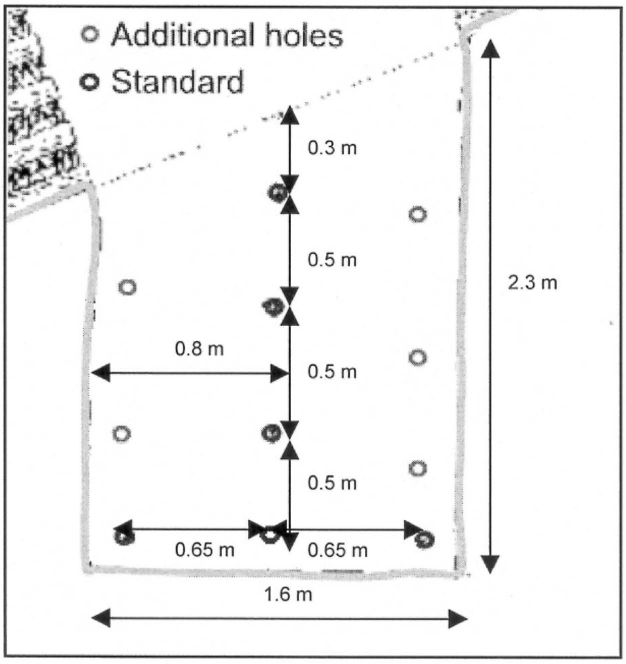


Figure 5—Placement of the problematic side blast holes

these holes is believed by many to assist in creating a smoother break of the gully shoulder, but management has stressed that these holes should not be charged up. These side holes, however, need to be spaced closely together (about 30 cm) in order to have this desired effect.

The problem is twofold.

- ➤ Drillers drill these additional side holes, which have been requested for by management, but the temptation to charge these holes is simply too great and the gully shoulder, on which a timber packs is to rest, is consequently damaged by the induced blast fractures.
- ➤ The spacing between consecutive side holes was, in general, noted to be so great that it is unlikely that their use will have any significant effect on the smoothness of the induced break. In fact, the mine standard makes no mention of these side holes in the first place and it has been shown on numerous occasions during AEL demonstrations that the current standard (without these side holes) works well when the correct burden, spacing and timing is used.

A solution to this problem is simple—

- ➤ It begins with the education and continual coaching of the entire stope team so that confidence is restored in the original mine standard. Workers need to be convinced that the standard does work if the correct timing sequence and spacing of holes are used.
- ➤ The next step is to completely discourage the drilling of the additional side holes in the gully face. Unless an impractical number of them are drilled, they will serve no beneficial purpose. What they do however, is waste valuable time that could be used to a much better avail. It should also be noted that if these side holes are not drilled, then it removes the temptation to charge them up and the subsequent damage to the gully shoulder is also prevented.

In general other areas of concern are:

- ➤ Incorrect line being drilled—drilling under the timber packs
- ➤ Too large a burden and spacing between holes (often as large as 0.7 m between the top hole and the free face).

Gullies not cleaned

In **Appendix 1**, 100% of the gullies studied are referred to as being not clean. The criterion on which this was based was whether a worker could walk upright, the entire length of the gully. It is, thus, no surprise that none of the gullies studied passed the criterion, but it is most important to note that the failure to keep gullies clean is a significant problem that needs further analysis so that a solution can be found.

The implications of a strike gully that is not clean are as follows.

- ➤ Damage is done to the gully hangingwall and sidewall support due to lack of passing space for the scraper.
- ➤ Employees are unable to examine hanging- and sidewalls to identify hazards/adverse fracturing conditions. It thus becomes much more difficult to control the gully condition since it is first noticed only once the damage has been done.
- ➤ Revenue is lost since the broken ore is stagnant in the gully instead of being treated for gold extraction.

Incorrect use of split sets (tendon support)

(Squelch, Adams *et al.* 1999) found evidence in fatal accident and injuries statistics to suggest a lack of timely installation

Photograph 3—Split sets installed in cubbies only after initial failure has occurred

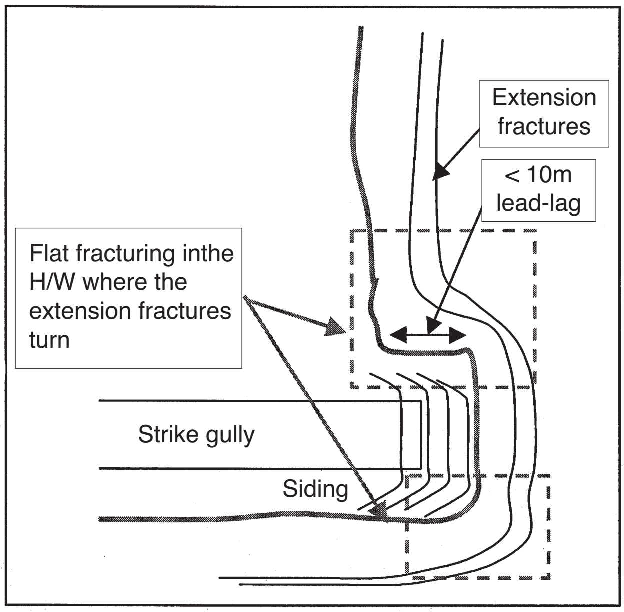


Figure 6—The flattening of extension fractures as they bend into the abutment (pillar)

and/or poor installation of gully support as being the possible cause for such injuries.

Two main areas of concern need to be addressed.

➤ 90 % of all split set related transgressions were due to the split sets not being installed within 1 m behind the gully face (Appendix 1). On average over the 11 studied gullies the first row of split sets were installed 4.2 m behind the gully face. This relates to roughly 5 blasts, or assuming 3 blasts a week, almost 2 weeks worth of extra time in which the gully hanging is not supported. A direct result of this is the irreversible opening up of mining-induced extension fractures within the hanging. Opening of fractures results in a decrease in the horizontal clamping forces within the hanging, and thus a greater possibility of a key block falling loose results.

➤ Another very common form of malpractice takes place in the winch/water jet cubbies as well as at strike/dip gully intersections.

Typically one tends to find that the split sets are only installed after a fall-of-ground has already taken place.

This has two shortcomings:

➤ The initial fall could damage equipment in the cubby

➤ Horizontal clamping forces in the hanging have been lost.

The following approaches should be considered for improvement.

➤ Implement an INCENTIVE programme in which the team is rewarded should their split sets be up to date and to standard. This is a controversial issue; where on the one hand it makes sense that in order to get people to act a certain way, they will require incentive, it must be said that the reward (if monetary) should not be large enough so as to blind the workers from the importance of face advance. Perhaps the incentive should be driven by the creation of awareness of the dangers and consequences of not installing tendon support to standard or by the creation of an additional use for the split set as proposed later.

➤ Note that the suggestion to discourage the drilling of side holes in the gully face (see blasting section) could be advantageous to the split set problem as well. The time saved, since side holes will no longer need to be drilled, can now be used to drill the two necessary holes in the gully hanging so that the split sets can be kept within 1 m from the gully face.

Sub-standard siding depth and panel lead-lag (face shape)

Basic rock engineering principles state that an extension fracture will flatten when it is forced to bend. This is one of the drawbacks to the leaving of strike stability pillars. The bending of the fractures around the top and bottom of the mini-longwall as they concentrate in the pillar, results in the development of flat hangingwall fracturing (Figure 6.). The carrying of a siding thus attempts to remove the strike gully (and subsequently, the workers) from the area prone to these flat-dipping extension fractures and the potential FOG threat they pose.

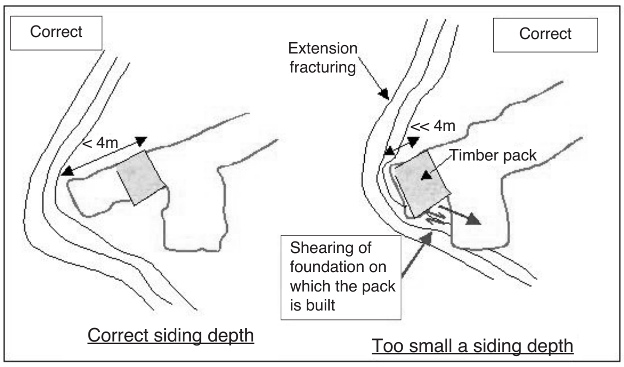
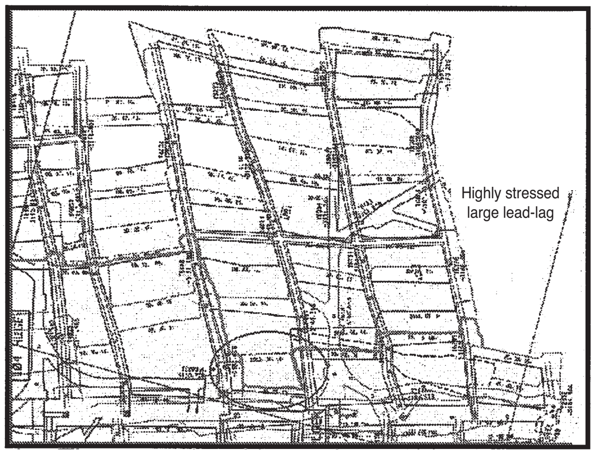
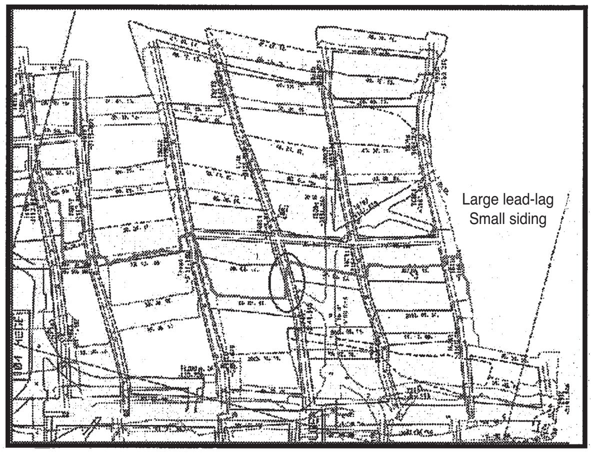


Figure 7—The deterioration of the gully shoulder due to the carrying of too small a siding depth

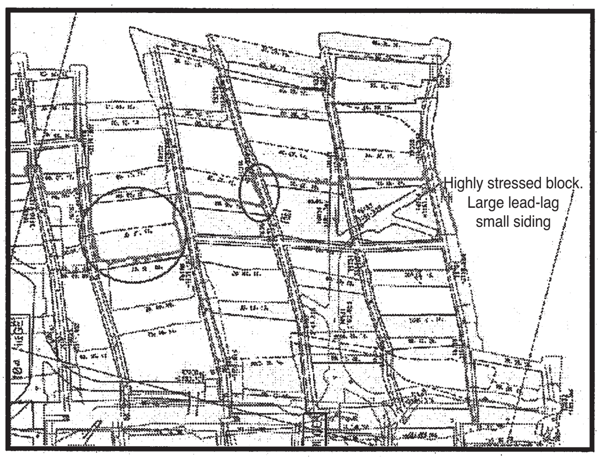
North



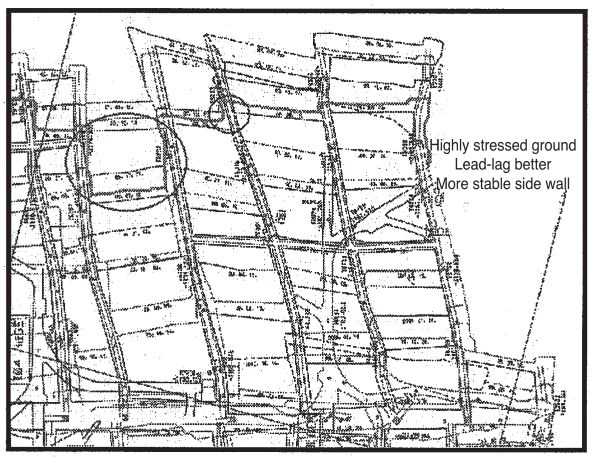
1. The upper (north) panels are driven far ahead. Notice the large lead-lag



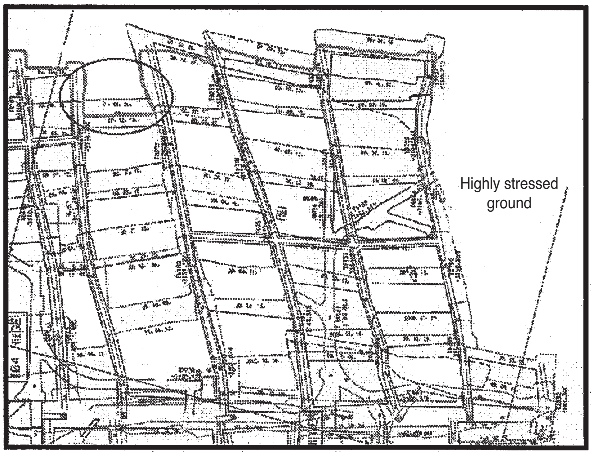
2. The large lead-lag is still carried as well as a small siding depth. The gully shoulder was in a poor condition here



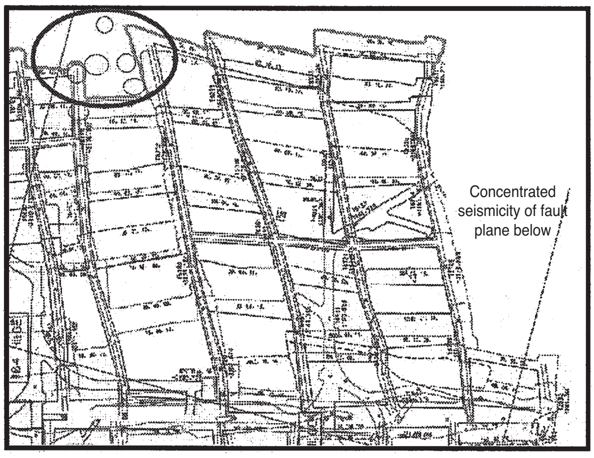
3. Gully shoulder was still in a poor condition. Note the block of highly stressed ground to the left (further north)



4. Lead-lag is reduced and a good siding depth is maintained. A drastic improvement in the condition of the gully shoulder was noted



5. Note that the highly stressed area has still not been corrected



6. Seismic activity concentrates on a fault surface 100 m below this area

Figure 8—Series showing how the carrying of an incorrect face shape can affect mining

The effects of carrying too small a siding depth can be serious and the problem is well illustrated in Figure 7. The section through a typical reef excavation, shows how if too small a siding is carried and the strike gully is deep, the extension fractures bending around the excavation may cut into the gully shoulder (on which the timber pack rests) causing the rock to wedge and shear out.

The effect of carrying a non-uniform face shape with large lead lags and too small a siding depth are well illustrated in the series of pictures (Figure 8). Pay attention to the 3rd strike gully from the right, which was visited in the survey.

As already mentioned, a relationship between siding depth and lead-lag seems to exist. A large lead-lag with a small siding ensures either

- Flat dipping (<40°) fractures in the H/W or,
- A highly fragmented gully shoulder (depending on the orientation of the strike gully to the side abutment).

A case was noted where an above-standard siding, in excess of 4 m, still resulted in flat extension fractures, but a lead-lag of 21 m was being carried. However when a 7 m or less lead-lag was carried sidings much smaller than 4 m were often adequate.

The following is suggested:

- Maintain lead-lags well below 10 m. A lead lag of 7 m or less with a 4 m siding depth will ensure steep-dipping hanging extension fractures and it is suggested that a standard of 7 m be adopted.

Photograph 4—Typical undermining of timber packs due to off-line gully development

If, due to a particular mining strategy, longer lead-lags are required then the siding depth is to be increased to suit. (Figure 4 can be used as a rough estimate, but it is suggested that further research be done in this regard).

Off-line gully development

Gullies developed off line result in the undermining of the timber packs as the gully scraper passes.

It is clear in the picture that the timber pack is offering less than half the areal coverage it should and a fire hazard is also created as the scraper cable cuts into the timber.

The problem arises as a combination of a lack of the provision of proper survey pegs and lines near the face, and the negligence of the workers to use these pegs and lines when they are provided.

The provision problem has been due to a shortage of trained surveyors and a lack of surveyor assistants. When a fall-of-gully-hanging occurs then all pegs and lines as far as 70 m back can be lost. These then all need to be replaced before a peg and line can be placed near enough to the face so that it is practically possible to use it for direction.

A plausible solution to this problem is:

The utilization of the centre-most split set in the 1:2:1 gully hangingwall pattern to serve as a 'backup system' in maintaining the proper gully line when pegs and lines are not available. This idea has been proposed before and suggests that the centre split sets should be installed exactly on the gully centre line. In this way, should a fall-of-ground result in survey lines and pegs falling out or being far behind the face, the centre split sets still maintain the proper line. Negligence of the workers to utilize the provided line is a supervision and training issue. A challenge linked with this concept is that drillers will need to place the centre split set holes accurately.

This option could also help improve the split set problem (dealt with previously) by creating in the workers an added awareness of the importance of the split set; not only is the split set to offer support but also offers surety in maintaining the proper gully line. Other options and new technologies like the use of laser and infra-red beams are also to be considered.

Conclusions

The following areas have been ranked in order of importance as being the most critical role players in the deterioration of strike gullies.

Poor blasting practice

The greatest culprit in terms of blasting practice is the drilling and charging up of blast holes close to the gully sidewall. Management never intended these to be charged up but the temptation underground is simply been too great, resulting in excessive fracturing of the gully shoulders during blasts.

Gullies not clean

This was found to have only a minimal effect on stability at TauTona, but is a common problem throughout industry.

Gullies, which are not clean, result in reduced passage for the scraper, a higher degree of risk due to poor visibility within the gully and tonnage discrepancies. Great opportunity exists in the analysis of this difficult to control problem.

Sub-standard siding depth and lead-lags

The effects of carrying an incorrect face shape are severe. The practice can result in induced seismicity, poor ground conditions and failure of timber pack support.

Split sets

90% of the problem lies in the late installation of split sets within the gully hangingwall. Standard requires that split sets be no less than 1 m behind the gully face. Irreversible opening up of extension fractures results in poor ground conditions. Also a problem is the delayed installation of split set support in winch and water-jet cubbies.

Off line gully development

Turning gullies result in the undermining of timber packs and an overall reduction in gully stability. Straight gullies are an essential requirement if a reduced gully width is to successfully be used towards improved stability. Observations indicate a greater tendency to this problem in the UCL.

Adverse geological features

Excessive 'criss-cross' fracturing, almost exclusive to the LCL, was noted to result in failure of the gully hanging even when all mine standards are followed and all support is in place. Failure is 'key block' initiated, starts in the 'stick side' and then propagates outward into the gully hanging. Shotcrete is at present the most attractive means of increasing areal coverage so as to prevent this failure.

The study also identified the following points of interest.

- ➤ Records having the detail required by the rock-engineering department are scarce. With the implementation of 'Fall of Ground' campaign and the proper inter-departmental communication in the future, more representative records will be available in the years to come.
- ➤ A substantial amount of evidence was highlighted to suggest that a greater tendency to adhere to mine standards exists in the LCL ('more hazardous' areas). 'Less hazardous' areas (UCL) tend to take more chances. It has been suggested that this is a human related phenomenon showing workers working harder when the risk is higher.
- ➤ A relationship appears to exist between siding depth and panel lead-lag. A linear estimation of this relationship is given in Figure 4. It is recommended than further research be devoted to the exact determination of this relationship.

It is suggested that the following be considered as a means towards improved gully stability.

- ➤ Investigate and implement the use of shotcrete or other super skins on the hangingwalls of gullies situated in adverse ground conditions. Special attention should be paid to the 'stick side' from which failure tends to originate.
- ➤ Preventing the drilling of side holes in the gully face blast pattern will allow for additional time in which tendon support can be kept up to date. It has been shown that they are essentially unnecessary and once drilled, only serve as a temptation to overcharge the gully face.
- ➤ Ensure split sets are installed 1 m behind the gully face so as to prevent opening up of fractures. Make use of the additional time made available by point 2 above and the use of an incentive programme should be investigated.
- ➤ Where possible, maintain lead-lags below 7 m whilst using a 4 m siding depth. If larger lead-lags are necessary the siding depth is to be increased to suit.
- ➤ Decrease the gully width standard to 1.2 m (especially in 'high risk areas'). As long as the decreased width does not hamper normal movement within the gully (requires a straight gully!), a reduction in width can only bear advantages for gully stability.
- ➤ Utilize the centre split set in the 1:2:1 pattern as a 'back-up' system in maintaining the proper gully line should pegs and lines not be available.

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OBITUARY

T.L. Gibbs

1911–2002

Tommy Leonard Gibbs served both mining and metallurgy during the golden years of the industry, when new goldfields opened, when large copper mines came into production, when the platinum industry expanded.

Tommy Gibbs was born in Nigel on 26 May 1911.

From 1925 to 1928, he attended Heidelberg Volks High School, from whence matriculated first in the Transvaal.

He read Engineering at the University of the Witwatersrand from 1929 to 1932, when he was conferred with the degree of B.Sc. (Eng) (Mining and Metallurgy). Whilst at Wits, he played rugby for Wits from 1929 to 1931 at scrumhalf, captaining the side in 1931. Also in 1931, he played for Transvaal as was a member of the SA Universities' combined tour to Kenya.

After some years as an official on the gold mines, Tommy joined the Government Department of Mines in 1935.

The Second World War shaped many South African lives—not the least, that of Tommy Gibbs. He saw time in north Africa and in Italy. He was a Sapper, rising to the rank of Major, commanding the 13th Field Company of the South African Engineering Corps attached to the 8th Army.

The SA Engineering Corps was legendary in the war.

Lt-Col Campbell-Pitt wrote 'The SAEC was a remarkably fine Corps. I should not be far wrong in saying that there was not a better one in all the armies of World War II. It was efficient because it was recruited mostly from engineering personnel. Its officers and many of the non-commissioned ranks were engineers of professional standing'.

Field Marshall Montgomery told Field Marshall Smuts that he considered 'the South African sappers to be among the finest in the world'.

Jack Kros in his book 'War in Italy' says 'Whereas her allies tried to turn soldiers into engineers, South Africa started with experts and turned them into soldiers'. On page 140 of his book, Jack Kros further states '13 Field Company under the command of Major T.L. (Tommy) Gibbs, was required to lift mines, rip up railway lines, fill in bomb craters, build a Bailey bridge across the Rapido River and convert the railway embankment west of Cassino into a road for the start of the advance. Given twenty-six hours to complete the task, they did it with eight hours to spare'.

Tommy Gibbs was awarded an M.B.E. and the Military Cross.

Mr Bert Hudson remembers Major Gibbs of the war years as a fellow member of the Red Devils as the men of the 13 Field Company were called. He remembers that they were attached at some time to a New Zealand Regiment and therefore there was a lot of tough rugby played. He says that Tommy Gibbs was a hard man and the team was not allowed to lose a match when he was in the side, and to his recollection they didn't.

Tommy Gibbs was closely associated with metallurgy in South Africa and this association lasted from 1954 to 1981—a period of 27 years.

In 1954 he became a member of the Management Committee of the Government Metallurgical Laboratory. He was appointed Chairman of that committee in 1960. When the Government Metallurgical Laboratory became the National Institute of Metallurgy in 1966, he served as a member of the Executive Committee from 1966 to 1981.

In the book 'The Story of Mintek' Jack Levin says 'special mention must be made of T.L. (Tommy) Gibbs—because of the length and value of his services. They began in 1954, when Gibbs was an alternate to the Chairman of the Management Committee, and for most of the twenty-seven years until his retirement from the Board of Control, he was chairman or a member of one or other of the bodies that supervised, controlled, managed, or advised—depending on the designation of the body concerned—Mintek and its forerunners.

Tommy Gibbs was appointed G.M.E. in May 1960, a post he held longer than any of his predecessors. He retired in 1976.

In addition to the normal duties of G.M.E., he was Chairman of the Mining Leases Board. During his reign, new large gold mines came into being, these included Bracken, Leslie, Zandpan, Kinross, Kloof, Vaal Reefs South, Elsburg, East Driefontein, Unisel, Deelkraal, Elandsrand, and the Cooke Section of Randfontein Estates. Other large mines which also came into being were Palabora Mining Co., Prieska Copper Mine, Impala Platinum Mine, Western Platinum Mine, Atok Platinum Mine. Coal mines, which came into being, were Optimum, Zimbutu, Kriel, Delmas, Usutu, Matla, Sasol II, Ermelo, Arnot, Umgala, Balgay, Aloe Anthracite, Indumeni. And, finally, to complete the picture with diamonds, Finsch diamond mine.

During the sixties and early seventies, was also the time of the closure of ageing Witwatersrand and East Rand mines.

Tommy Gibbs was also Chairman of many Councils and Committees' of Health and Safety, of goverment assistance to marginal mines, of research into strength of coal pillars, etc., etc. It has been said that Tommy was the last of the G.M.E.s who saw themselves as the highest professional engineer in government and who spoke directly to the Minister of Mines, bypassing Deputies and Secretaries of Mines, much to the latter's chagrin.

Tommy Gibbs was one of the great men of South African mining and metallurgy:

- a man who served with distinction in the Second World War as a sapper bringing honour to South Africa
- a man who held the reins of the Government Mining Department during the golden years of South African mining, guiding the industry to prosperity
- a man who served the South African metallurgical industry in the highest echelons for 27 years
- a man who has lived a long and full life
- a man who in the past has been one of the Institute's honorary Vice-Presidents
- a man who was a Life Member of our Institute
- a man who was always a professional as an engineer.

At the 2001 AGM of the SAIMM, Tommy Gibbs was awarded the Brigadier Stokes memorial award, the highest award offered by our Institute. ◆