Mine Call Factor. Unaccounted for Gold, was it there in the first instance?

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INTRODUCTION

The mining industry has until recently (1996) been in survival mode due to a constant gold price in dollar terms. The devaluation of the Rand is responsible for a more comfortable financial position for gold mines and capital investment for expansion to a lesser degree. However, a persistent problem in many mines is a low Mine Call Factor. This indicator appears to be decreasing with increased pay-limits that have become the order of the day. Increased mining of pillars also has a negative influence on the Mine Call Factor.

Gold Unaccounted For as indicated by the Mine Call Factor traditionally attracted some exotic explanations, some of which are still in vogue today.

The Mine Call Factor is influenced by a multitude of variables, which were systematically examined to distinguish between fact and fiction. This paper examines the gold in-situ estimates, some mining methods and experimentation results in the metallurgical plant. Although gold theft is a real and increasing problem in the industry, it only explains a portion of the unaccounted for gold and will not be further discussed in this paper. Obviously the relative percentage stolen increases with the drop in the output from the plants.

Statistical analysis and large-scale experiments were conducted to examine possible influences to the Mine Call Factor. The study was confined to Freegold, with specific reference to Western Holdings Mine.

This paper deals with some of the experiments and conclusions made during the study.

MINE CALL FACTOR

The ultimate gold mining efficiency measure is the Mine Call Factor. It is the ratio, expressed as a percentage, of the specific product accounted for in recovery plus residues versus the corresponding product called for by the mine's measuring methods. It should ideally equate to approximately 100 percent.

In the Mine Call Factor equation, the gold accounted for minus the Gold called for equals gold unaccounted for. The unaccounted for which is a theoretical gold loss can be split into real gold loss and apparent gold loss.

The industry is riddled with sometimes mystical connotations to the possible causes of the unaccounted for gold. A systematic scientific approach was used to sift fact from fallacy in the quest to find reasonable explanations for this theoretical gold loss.

GOLD LOSS

The real gold loss should be traceable and if lost during mining operations it should be able to be found underground. If it cannot be found underground it can only be ascribed as apparent gold loss (Graph 1). The real gold loss underground is exaggerated in general as will be described in subsequent paragraphs.

The gold called for as per the mine's measuring system including sampling, assaying and tonnage is an estimate. It is therefore valid to raise the question on the traditional viewpoint of gold loss of whether it was there in the first instance?

Apparent Gold Loss

In-situ sampling

Indications are that the gold in-situ is over-estimated which results in an apparent gold loss. The portion of the apparent gold loss can be ascribed as being the rudimentary method used during in-situ skin sampling of the ore reserves and the subsequent over-estimation of gold content. This is particularly true in reef types where the gold is concentrated in the contact region such as Carbonaceous Basal reef. In the instance of bigger conglomerate reef types such as Leader Reef it is not as pronounced because the gold is distributed throughout the channel. This can be minimised by proper sampling methods.

Experimentation was done with the use of a compressed air-powered angle grinder using a 100mm diamond blade to cut the outer perimeter of samples. The 100mm angle grinders are available off the shelf but need to be fitted with a small lubricator. The use of hand-held water sprays is recommended to keep dust levels down.

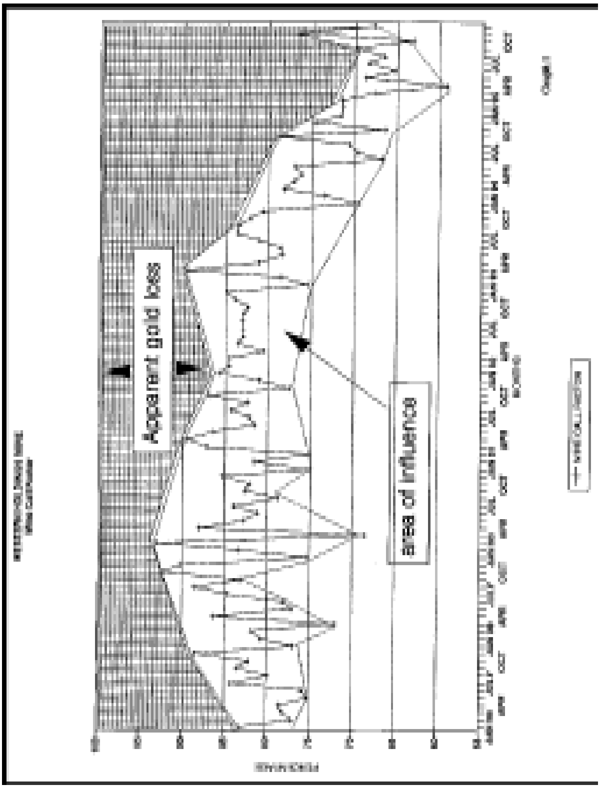
Experimentation to compare the grade values obtained using the aforementioned method and conventional chip sampling directly adjacent to each other, proved fruitless as the grades are extremely variable in the x, y and z planes. It was however concluded from underground observations that conventional chip sampling is definitely less consistent when compared to using diamond blade cutting of samples. Western Holdings Mine continues to introduce these units to assure more consistent sampling methods.

Over-inspections of samplers to ensure quality control are a requirement. This aspect of sampling has deteriorated and is almost non-existent due to the reduction of staff in recent times.

When sampling is not done properly, no amount of statistical analysis can guarantee accurate predictions of in-situ grade.

Specific gravity

Experimentation indicated that the specific gravity of the ore at 2 780 kg/m≈ is over-estimated and that it should rather be in the vicinity of 2 700 kg/m≈. The result of this over-estimation is that an apparent gold loss is created in that the grade content and tonnage of the ore is over-estimated (Table 1).



Graph 1

Table 1

Specific gravity (Over-estimation results)

Assumed reef Specific Gravity (kg/m³)	Actual reef Specific Gravity (kg/m³)	Tons mined as % of base	Overall grade Au (g/t)	Overestimation of Au as % of base
2780	2780	100	5	0
	2700	97.0	4.86*	6

Table 2 is a summary of specific gravity results as determined from various samples. It remains for individual mines to introduce true specific gravity to decrease the apparent gold loss that can amount up to approximately 10 percent of the theoretical gold loss.

- Particular attention should be paid to the density of the rock from which the sample is taken. The extrapolation of the grade across the face will be inaccurate if there is a differential in the density between the remainder of the sampled face. It has been found on other mines that the specific gravity of carbon samples are in the region of 2 000 kg/m≈, which is extremely important in the instance where vacuum cleaners as a primary mining tool is being used.

Table 2

Specific Gravity results

Lithology	No of samples	Mean t/m³	Standard Deviation
Footwall (UF1)	11	2.655	0.007
Basal conglomerate	16	2.754	0.134
Basal reef quartzite	12	2.663	0.023
Sandbar quartzite	4	2.663	0.033
Laminated quartzite	8	2.719	0.107
Khaki shale	12	2.812	0.056
Waxy brown Leader quartzite	9	2.667	0.039
Leader reef quartzite	10	2.663	0.015
Bedelia conglomerate	16	2.728	0.057
Bedelia hanging wall	5	2.698	0.049
'A' footwall conglomerate	5	2.684	0.009
'A' footwall quartzite	5	2.684	0.015
Witpan reef (lower)	5	2.804	0.053
Uitsig reef (upper)	5	2.896	0.199
'A' hanging wall quartzite	5	2.660	0.012

Real Gold Loss

The legendary gold accumulations due to previous losses underground were found in relatively insignificant proportions underground when the unaccounted for gold is considered.

Sweepings

Fines are likely to be lost during any part of the mining process, with the greatest chance of this happening in the stope. Sweepings in a stope refers to the removal of the finely-divided ore in which it is believed much of the richest portion of the ore is found. This operation is routinely performed, concurrently with stoping, most of the time. There is normally an unexplained delay in performing this task as a simultaneous part of the mining cycle, resulting in month end rushes to get the job done. When this part of the mining cycle is delayed in areas with bad hanging wall conditions, the gold lock-up can be lost. Falls of ground in the back areas prevent the future recovery of these losses. It is therefore important to do the sweepings concurrently with blasting operations.

Sweepings are accomplished by using brushes to sweep up the footwall. This is done subsequent to the blasted rock being removed from the panel, using scrapers. A minimum amount of water is used during this stage, as it is believed that the fine gold particles are washed into the crevices. The footwall is finally washed over with water to remove the gold left behind.

Sweepings are passed as clean by the survey department by means of samples taken of the fine material left after the sweepings are completed. It is a quantitative measurement because it relates to the volume of fines per square metre of footwall.

The Mine Call Factor is believed to be strongly influenced by both the quantity and quality of sweepings done during a specific production period. This concept was statistically evaluated and it was found that sweepings per sé is not the major contributor to a good Mine Call Factor, but that it is rather an indicator that the majority of the tonnage was removed from the stope. It is however, not suggested to decrease sweeping efforts as the Mine Call Factor will then definitely decrease.

The correlation coefficient between the Mine Call Factor and sweepings percentage for 6 mines amounted to 0.0011, 0.1174, 0.0534, 0.0721, 0.0312 and 0.02848, which was statistically insignificant. (0.0927 is statistically significant at a 95% confidence interval with 42 observations and 40 degrees of freedom)

Footwall cracks

It is generally believed that fine cracks in the footwall are the recipients of the minute free gold particles. The particle size (microns) and spatial location of the gold particles lends itself to being lost.

An experiment was conducted to quantify the amount of gold remaining on or in the footwall subsequent to sweepings having been completed. The stope selected was mined out on open stoping at a grade of approximately 20g/t from the Basal reef, Steyn facies (Carbonaceous). It was passed as swept and vamped. Dry sweepings, using as little water as possible, were practised during the mining of these ore reserves.

On further investigation, the stope was estimated to contain approximately 60 tons of fines at a grade of 30 g/t in 5 000m″. This stope did not meet the quality standards of being been passed as swept and vamped as required by the mine standard.

A contractor was hired to supply and install a vacuum cleaner, operate it and retrieve the ore in bags so that it could be transported to the plant for gold extraction.

A 55 kW liquid ring vacuum pump capable of creating -85 kPa, using a 100mm suction hose, was installed in the stope. The collector bin capturing the ore in 20kg size bags, was advanced to remain within 30m of the suction point, using 100mm HDPE pipes. A dust scrubber was installed between the collector bin and the vacuum pump to remove the dust liberated during suction. Heat created by the pump was dissipated by means of water.

A maximum of 0.17 ton per hour of ore smaller than 100mm diameter was achieved (1 755kg in 10 hours). The average figure amounted to 0.11 ton per hour (21.42 ton, 39 shifts @ 5 hrs.) A maximum of 5.34 tons was vacuumed during a 12 shift period (6 days).

Table 3

Grade distribution in the stope

Period	No of samples	Average Grade (g/t)	Standard Deviation	Variance	Highest and Lowest value (g/t)	Ton-nage
1	38	24.81	10.45	109.3	59.2 / 5.7	3.76
2	27	437	487	237 592 *	2251 / 13.8	4.2
3	78	22.8	18.28	334.4	88.4 / 1.6	4.08
4	77	29.5	8.48	72	57 / 14.6	5.34
5	40	54.1	30.96	958	197.6 / 17.2	4.04
6	35	26.1	30.02	901	99.5 / 0	2
7	19	35.61	13.3	176.9	58.5 / 11.4	3.08
8	38	41.54	14.76	217.9	94.5 / 13.1	5.48
Total	352	62.7	174	3 027.9	2251 / 0	31.9

* Reef in footwall was found.

- Period 1 (1995 February 13 to 19). Bulk ore and visible fines vacuumed.
- Period 2 (1995 February 20 to 24). Bulk ore, reef in footwall and visible fines vacuumed.
- Period 3 (1995 February 25 to March 3). Bulk ore and visible fines vacuumed.
- Period 4 (1995 March 4 to March 10). Started to vacuum from footwall cracks.
- Period 5 (1995 March 11 to March 16). Fines only, brushed from the footwall.
- Period 6 (1995 March 17 to March 25). Fines only, brushed from the footwall.
- Period 7 (1995 March 25 to April 7). Fines only, brushed from the footwall and special tests.
- Period 8 (1995 April 8 to April 14). Fines only, brushed from the footwall.

Refer to Graph 2 for grade distribution.

Special test conducted

- Lifting of footwall slabs

Several footwall slabs on the up-dip side of the strike gully were lifted to determine the gold content trapped underneath. The results were as follows:

Table 4

Grade of fines vacuumed

Description	Value (G/T)
Underneath pack gully +0.7 m	1.5
Gully +0.8 m, 1.0m deep	13.2
Gully +0.5 m, 1.0m deep	11.4
Gully +0.7 m, 1.0m deep	8.1
Gully +1.0 m, 0.9m deep	84.6
Gully +5.0 m, 0.5m deep	10.3
Gully +3.0 m, 0.6m deep	trace
Gully +1.6 m, 0.8m deep	2.2
Gully +4.0 m, 0.5m deep	6.6
Underneath pack up-dip of gully	22.6
Gully +0.2 m, 1.1m deep	4.1
Gully +0.8 m, 1.0m deep	19.8

The volume of fines associated with these values were in all cases, insignificant.

- Volume vacuumed in 2m x 2m grid.

A block of footwall was divided into a 2m x 2m grid and vacuumed for ±15 minutes. The 100mm suction hose from the vacuum cleaner was split into three separate 25mm pipes so that fines could be vacuumed simultaneously from three different areas within the grid. The area was vacuumed to a depth of 15cm and waste sorting was done.

The fines were collected into bags for each 15 minute period. The bags were marked and the vacuuming system flushed after each 15 minute cycle. These bags were individually weighed and individually evaluated.

The results were as follows:

Table 5

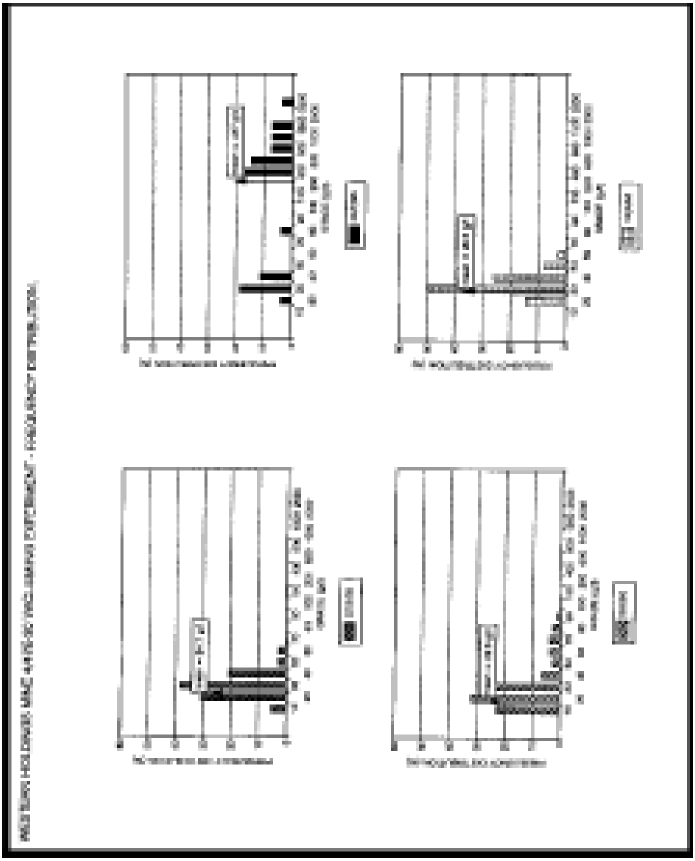
Results of vacuuming at 15 minute cycles

Position	Duration (min)	Weight (kg)	Grade (g/t)	Gold Content (g)
Block 1	15	3.4	13.2	0.0449
Block 1	15	6.9	16.9	0.117
Block 2	20	7.0	4.5	0.0315
Block 4	15	11.6	21.9	0.254
Block 4	15	3.6	9.2	0.0331
Block 8	15	8.4	11	0.0924
Block 8	15	8.2	3.0	0.0246
Block 8	20	12.0	3.8	0.0456
Block 11	15	8.9	5.6	0.05

It is obvious from the aforementioned that gold was not concentrated in the footwall cracks of this particular stope.

Conclusion of experiment:

- The fines that remained in this stope were largely due to unacceptable mining practice and not due to enrichment of fines in the footwall cracks or packs;
- Dry sweepings were practised in this stope;
- The sweepings done in this stope did not meet the mine standard;
- Reef left in the footwall (not picked up in previous records) accounted for the majority of the gold recovered from this working place. (±66 percent = 1.8kg);
- Gold does not seem to concentrate in footwall cracks as popular belief suggests. To date no place has been found where this supposed concentration of gold has taken place;
- Although an amount of approximately 2.5kg of gold in a volume of approximately 30 ton of ore was vacuumed in an area of



Graph 2

660m″, the project at best covered its cost. A higher volume of extraction is needed to make it viable. It is suggested that "high volume" of approximately 1 ton per hour at a grade of at least 30g/t must be vacuumed to have a positive contribution;

- The grade of footwall fines to be vacuumed can be expected to be higher than (approximately 150 percent of) the original face value. The amount of fines vacuumed was approximately 0.048t/m″, which is high. The quality standard normally practised by the Grade Officer when passing sweepings is that he would allow ± 50g/m″ in any continuous area.

The use of vacuum cleaners underground is becoming fashionable. The volume of rock broken underground can be curtailed significantly as a direct result of this mining method. It is believed that this method would reduce the areas for potential loss of gold because the gold is captured directly at the working face and thereafter transported in a closed circuit.

It cannot be assumed that a mine's grade problems will be resolved with the introduction of vacuum cleaners. Both a significant grade and tonnage vacuumed is required to make this operation viable. Vacuum cleaners used to clean-up areas where gold bearing ore remained from previous mining operations, can be viable. This will primarily be the case if a minimum infrastructure is required to remove the ore.

Vacuum cleaners used to prevent gold loss in a working stope will only be successful if the gold is in fact lost in the stope. Indications are that only a limited amount of gold remains in a stope after being passed as swept and vamped conventionally.

The use of waterjets

Conventional mining methods require the use of water during the cycle. The amount of water used, expressed in tons of water used to tons of rock produced, could play a negative role in the gold loss underground. It is perceived that the finer particles of gold released during the mining operation could be washed away during the washing over or drilling portion of the mining cycle. The introduction of waterjets on a large scale as cleaning tools, is perceived as worsening the possible loss in gold. It is believed that more water is used and that the increased water pressure assists in depressing the small particles into footwall cracks.

The hypothesis is that the velocity of the water used to move the rock on the footwall of a working place is such that it transports the coarser material, but the free gold is separated. The irregular flow of water when transporting the ore in a stope face encourages the loss of gold. The reef type mined will dictate its infinity for gold loss due to its inherent characteristics.

An experiment was conducted to quantify the increased gold loss in stopes using waterjets. The stope selected for the gold loss experiment was a high grade Basal reef stope. It had a stoping width of 110cm and an average grade of approximately 25g/t. The gold distribution was restricted to approximately 5mm of the carbonaceous layer in the Basal Reef.

The blasted rock was scraped from the face into a 25m long strike gully to the cross-cut using a conventional scraper. The ore was then mechanically loaded into hoppers and transported to the main tips from where it was transported ultimately to the surface metallurgical plant.

The gold loss was determined on a daily basis over an sixty shift period (Graph 3). The reconciliation of the gold from the face to the tipping point took place under varying conditions:

- Conventional cleaning using scrapers,
- Introducing a waterjet to assist with scraper cleaning,
- The sealing of footwall cracks in the strike gully.

Conclusion:

The **theoretical gold** loss in this experiment amounted to 37 percent of the gold mined in the stope as determined using grab samples. Although grab sampling is not accurate, the errors are mutually inclusive and the results can be used for comparative purposes. The **real gold loss** is significantly less because there was no major lock-up of ore remaining in the stope. Selected areas that were previously passed as swept were vacuum cleaned to determine the gold left behind. The volumes of gold were insignificant and do not explain the **theoretical gold loss**.

It was also attempted to seal a gully using a cementicious based product. Although it withstood the abrasion of the rocks and scrapers remarkably, it did not appear to make any significant difference to 'gold loss'.

The gold loss in this stope was directly related to the gold called for in the stope. A linear regression analysis done between the gold called for in the stope and the gold accounted for in the stope confirmed that the correlation coefficient (R″) amounted to 0.95. The rate of gold loss was very similar between the different phases of the experiment. It is, therefore, concluded that:

- The use of a waterjet in this particular stope did not increase the rate of gold loss.
- The sealing of footwall cracks at this stage does not seem to be a viable proposition, because it has not been conclusively proved that a significant amount of gold is lost in the cracks.

Other observations of significance include:

- The rate of production increased with the introduction of the waterjet.
- Attention must be given to the complete water handling circuit in the case of waterjets, not just to get the water from the stope to the cross-cut.

Mud loading

One hundred and fifty six mud samples were taken over a distance of 10.2km over 4 levels (Graph 4). The samples were taken approximately 30m apart where the mud was spread fairly consistently. In some instances the distance between samples varied up to 280m apart. The average grade was 5.69g/t.(Head grade of the shaft is approximately 6g/t) The average depth of the mud was 0.42m (ranging from 0.1 to 2m) and amounted to 21 570 tons at a density of 1 700kg/m≈. The available gold amounted to approximately 123kg. Although this is a significant amount it confirms that the gold is not generally concentrated in the mud and that it certainly only amounts to a small portion of the real gold loss. It, however, remains a real gold loss if not finally recovered in the plant.

It can be seen from the aforementioned that a fair tonnage of mud is required to make a noticeable difference in the plant.

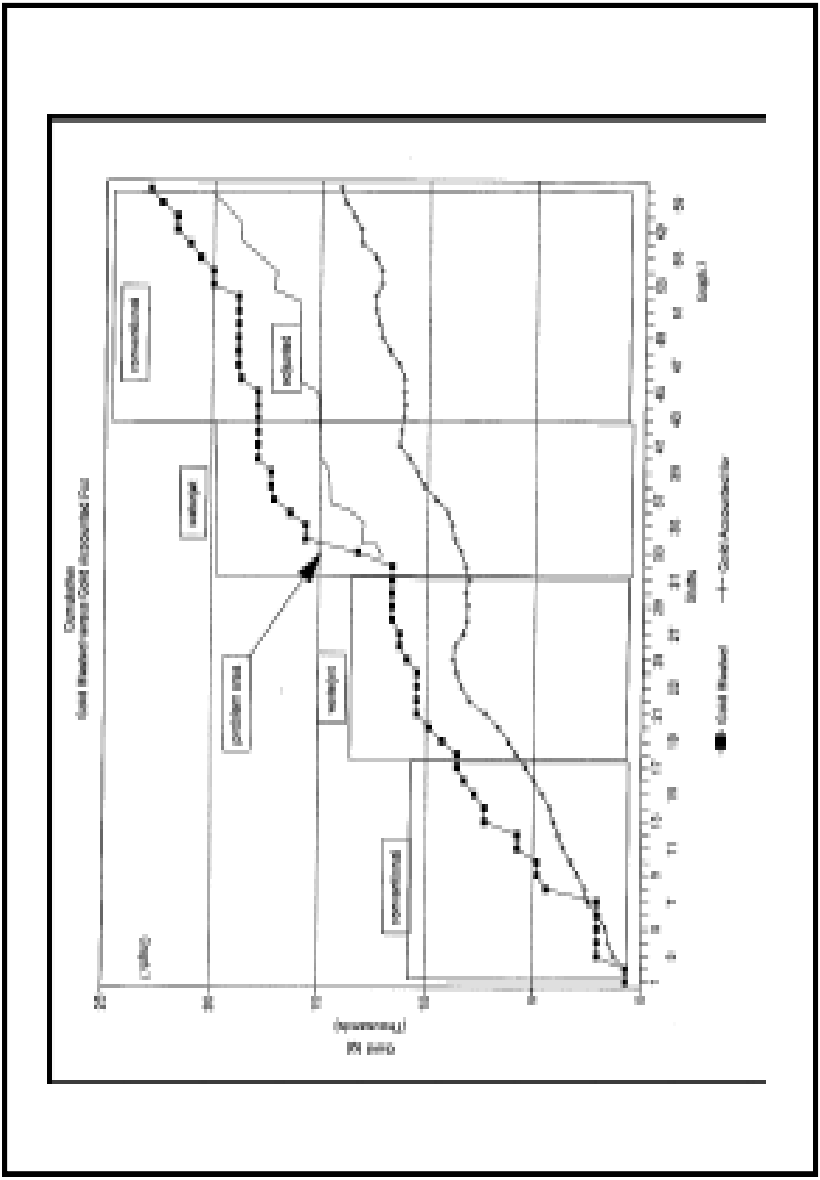
Mud loading in haulages and other access ways have not been given the proper attention in the past due to labour cuts and the profit margin squeeze. However, most mines or shafts getting to the end of their lives are addressing this area vigorously. Major vamping and clean-up operations are being conducted to coincide with shaft mining closure. A large volume of gold has been locked up underground as a result of this. The grade content of this mud in the footwall infrastructure approximates that of the reef plane in the surrounding areas.

Reef in hanging and footwall

Previously unaccounted for reef remaining in the footwall was found during an experiment. This type of gold loss is avoidable and is classed as 'dirty mining'. A similar occurrence of reef remaining in the hanging wall after a panel was undercut, is also avoidable in most instances. The objective of undercutting, is to remove the reef with as little as possible waste contamination. It certainly is not to remove as little as possible waste and leave the reef in the hanging wall. The accounted for areas where this type of avoidable gold loss occurs is of a relatively small proportion in the context of a progressively poor Mine Call factor.

In the earlier years reef was left or remained in the hanging wall in the then undercut stopes. Some of these areas have been found but not in sufficient quantity to explain the gold loss to date.

It remains important to adhere to clean mining principles in that all the payable reef should be removed during the mining operation and not be left for a second mining operation in time to come. It will invariably not be an economic operation subsequently.



Graph 3

Gold loss in the metallurgical plant through residues

It is a most convenient option to blame the metallurgical plant when a low Mine Call Factor is achieved. However, if the residue values are measured correctly, it cannot have an influence on the Mine Call Factor at all. This is the case as the gold-in-residue is part of the gold accounted for equations. The metallurgical process in a plant will dictate what residue values are acceptable to that particular plant.

GENERAL

Gold allocation through go-belt sampling

Go-belt samplers and weightometers were installed at all the Freegold shafts. It has been in operation on Western Holdings Mine since October 1995 and most of the problems were resolved. Analysis of the sampling results has indicated that stability has been reached and that gold produced can be allocated to the individual shafts using this method.(Graph 5)

This method is certainly different when compared with the gold produced allocation based on gold broken because the tonnage hoisted is not taken into account. In the periods of financial survival, it is a mining strategy to hoist ore broken from old areas in addition to that broken from current mining. The gold from the old areas is not called for but it does make a positive contribution to the gold produced. The allocation of the gold produced must therefore take into account the areas from which this additional effort stems. Gold produced allocation using the go-belt samplers and weightometers therefore is the correct method and will ensure that focus is placed on the deserving profit centres.

CONCLUSION

There are no mystical connotations to gold loss as the gold loss does not take place in obscure ways. The real gold loss primarily occurs because the ore blasted is not all removed to the metallurgical plant timeously.

The estimation of gold in situ needs to be further explored as indications are that the some of the gold was not there in the first instance.

ACKNOWLEDGMENTS

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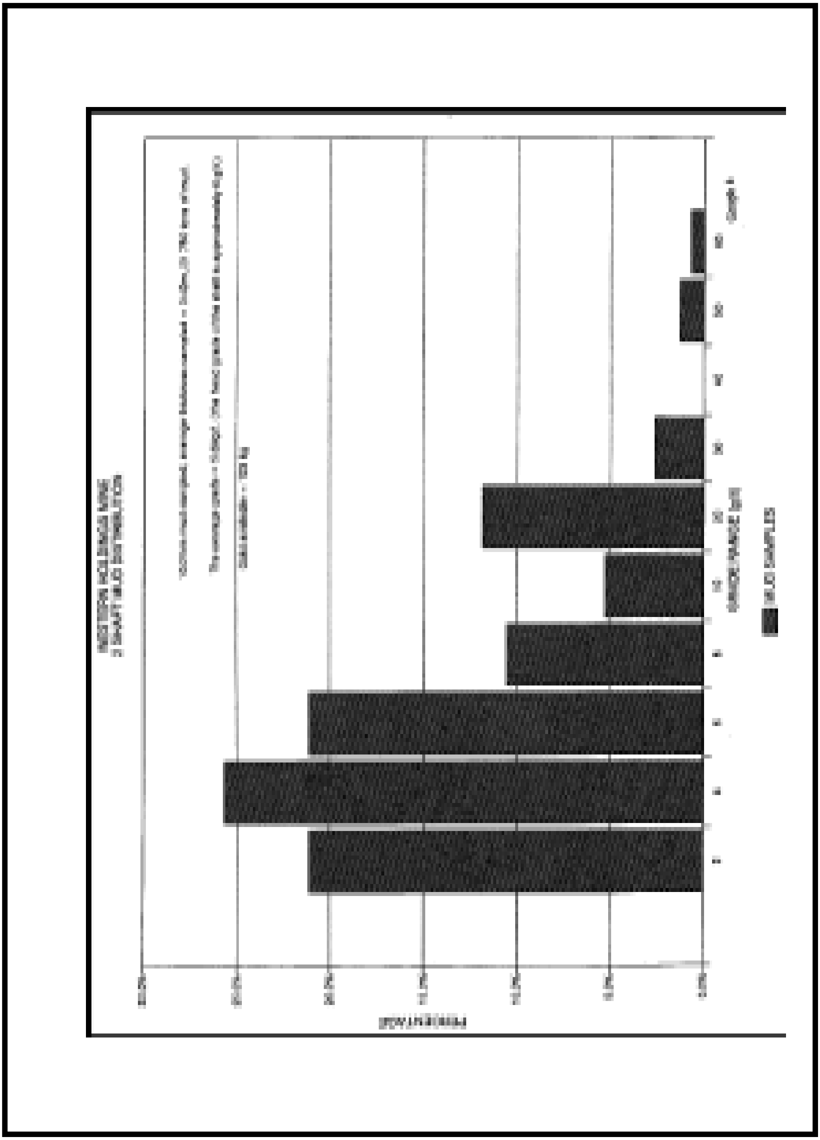
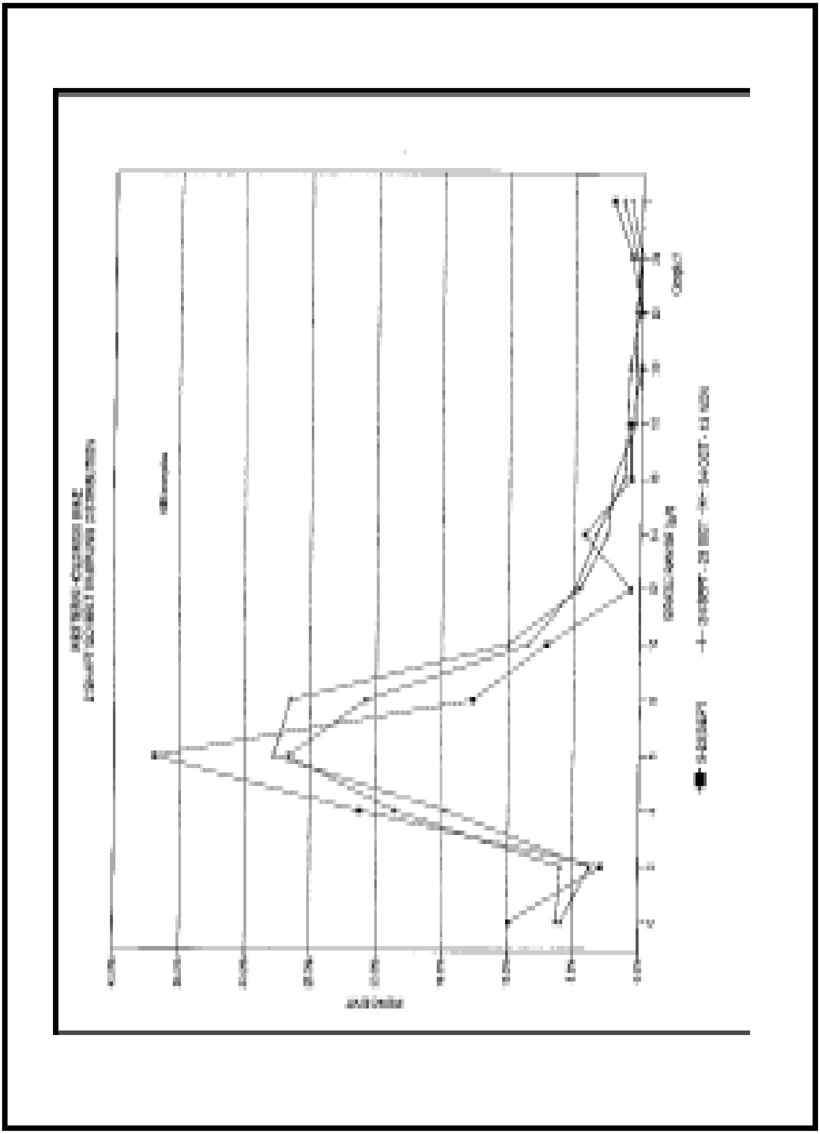


Graph 4



Graph 5