The Effect of Considering Density as Weighting Factor When Compositing Assay Grades and as Accumulated Variable on Mining Reconciliation

Paulo Dias[1], João Felipe Costa[2], Cássio Diedrich[3] and Vanessa Koppe[4]

Abstract The decision about where some material selected to be mined out should be sent is a routine during short term mining planning and operation. These decisions are mainly based on an economic cut off grade applied to the panel grade determined as the average grade of the SMUs within it. The quantity of material required to be mined for a given schedule, and the quality of the material influence these decisions. Therefore, an effort is spent to apply the most appropriate techniques to obtain precise and accurate estimates, avoiding misclassifications between the panels selected to be mined out based on long term estimates, and those more precise short term estimates. One among the various causes that can influence these misclassifications is the bulk density mistreatment when estimating a block. Density should be used when compositing assay grades as a weighting factor and as an accumulated variable when estimating grades. Otherwise, it can lead to some local under/overestimations of the panel grade. Various studies confirmed the impact on the estimates when density is not considered during compositing assays and estimating grades. Even though the importance of considering density as a weighting factor and as an accumulated variable is proved, the impact on the short term mine planning was not analyzed yet and the possible consequence was not covered in terms of mining operation decisions. In addition, there is an expected improvement on the quantity of metal when estimating block densities instead of applying an average density for a domain. This study reports the impacts of disregarding density as a weighting factor when compositing assays and when using density as an accumulated variable and the downstream consequences of misclassifying panels as either ore or waste panels based on a cut off. When analyzing this impact two methods are proposed: one disregarding the density and compositing grades taking into account

[1] Vale S.A., South Atlantic Operational Copper Department, Carajás, 68516-000, Brazil
paulo.mauricio@vale.com

[2] Federal University of Rio Grande do Sul, Porto Alegre, 91501-970, Brazil
jfelipe@ufrgs.br

[3] Vale S.A., South Atlantic Operational Copper Department, Carajás, 68516-000, Brazil
cassio.diedrich@vale.com

[4] Federal University of Rio Grande do Sul, Porto Alegre, 91501-970, Brazil
vkoppe@ufrgs.br

only the core lengths, and the other using an accumulated variable grade x density x length (GLD) and length x density (LD) obtaining the grade indirectly by the ratio GLD/LD. The results showed that when comparing these two approaches with a cut off grade it does not lead to different classifications of the selected panels to be mined out. In this case, disregarding the density as a weighting factor and as an accumulated variable did not change the destination of the mined material. However, even for small masses reconciliations the indirect method better matches the executed grades than the direct method, which can lead to economic consequences.

Introduction

The bulk density plays an important role on mine tonnage estimates as well as on the grade estimates. A current practice consists of using an average bulk density over a given geological domain or lithotype determined from a few samples collected from it. This practice has shown that for long-term reconciliation the expected tonnage is similar to the obtained tonnages. Conversely, for short-term reconciliation the tonnages and grade estimates usually depart from the predicted values.

A solution for this issue was presented by Vallée *at all* (1992) which suggests a systematic measure of bulk density as the sample grades. Consequently, density should be estimated for each block according to Laine (2003) in a case study involving block density estimates in a PGE-deposit, which stands out that the amounts of metal content in a block can be affected by using an average density instead of a density model.

Simultaneously to the metal reconciliation there is the grade reconciliation in which a large number of factors can contribute in different intensity to a poor reconciliation, such as the data quality, data spacing, ignoring physical grade controls on estimates, and also on how the reference grades are obtained. Among all possible problems between the data and the estimates there is one related to the compositing grade assays. Dadson (1968) and Baven (1993) pointed out that instead of compositing grades using only length as a weighting factor the density must be incorporated into the compositing process by weighting grades as the length, otherwise it can lead to overestimation or underestimation of the composite grades. In addition, Sinclair and Blackwell (2006) pointed out that compositing grades only by length, when density varies significantly over the deposit, constitutes a wrong way of compositing.

Another source of error concerns about using (or not using) density as a weighting factor when estimating block grades. The idea is to consider density as a weighting factor (accumulation) once density samples are not constant. Consequently, two composites with same average grade can lead to two different quantities of metal if they have two distinct average densities. A way to weight density when estimating grades is using an accumulated variable. Krige (1981) suggests that density should be incorporated as a weighting factor in all estimating procedures and Armstrong (1998) pointed out that it would be wiser to use the accumulated variables GLD (grade x length x density) and LD (length x density) when the density of the ore varies from place to place.

In a study carried out by Dias *et al.* (2011), two estimates for a selected block were generated and compared. The first estimate was made using Diamond Drill Hole samples composited only by length as weighting factor, and a second estimate using the accumulated variables GLD and LD, in which grades are composited by length and density as weighting factors. These estimates were compared to the grade obtained by the average grade derived from the Blast Hole samples within the block (consider as the reference grade at the mine site). The result showed that the smallest difference from the reference grade was achieved using the accumulated variables GLD and LD and the largest difference, using samples composited only by length. In order to convert the grade into metal content two densities were applied: one, equal to the average density of the domain where the block is located, and the other, estimated using density samples. Again, the difference into the block mass and metal content was smaller using an estimated density and grades using the accumulated variables GLD and LD.

This study considers the traditional approach and a proposed one. The traditional approach disregards density as a weighting factor on both compositing assays and estimating and it is referred as direct method (DM). The proposed approach composites grade assays weighting by length and density and estimates grade through the accumulated variables GLD and LD, and it is referred as indirect method (IM). These approaches are used to estimate long-term copper grades and evaluate the effect of these estimates on a short-term production schedule through reconciliation. It focuses mainly on where the predictable mine material should be sent, either to the mill or to the waste. The period analyzed consist of a three-year mining production.

Geological features of Sequeirinho deposit

The Sequeirinho deposit has a sigmoidal shape where the mineralization occurs as a continued succession of sub-parallel bodies with aggregate thickness varying from 20 to 300 meters. The mineralization is structurally controlled on the volcanic felsic rocks, granite and gabroic rocks where it is hosted. The major part of the hang wall is composed of a granite-tonalite rock, which presents some dikes and reminiscence of mafic rocks. The footwall is defined for a sharp contact that separates the mineralization from a weathered biotite-schist. This contact is also characterized by a decreasing on the chalcopyrite-actinolite-magnetite content against an increase of the saprolite-biotie content. The high grade sulfide mineralization zones occur in breccias, which is usually rich in Cu-Au near the contact between the mineralization and the footwall as well as in contact zones inside the mineralization model. The mineralized breccia has a chalcopyrite matrix with magnetite, amphibolite, and some litic fragments as clasts. The low grade mineralization zones occur commonly as stockwork and disseminated. A geological model is used as a physical structure controlling the mineralization. It constitutes a reference for the reserve limits.

Methodology

Two approaches were compared. The first is commonly adopted at the mining industry and consists of compositing grades using only length as a weighting factor and then estimating the blocks grades using ordinary kriging (OK). From now on, this approach is mentioned as DM (direct method). The second approach here proposed consists of weighting the assays by length and density to generate the composites and then creating the accumulated variables *grade x length x density* (GLD) and *length x density* (LD). Next, these variables were individually estimated by OK. The final grades are then obtained by returning the variables to their original scale, i.e., by dividing *grade x length x density* (GLD) / *length x density* (LD). This method is appropriate when the composite lengths are not constant (as usually they are not). Otherwise the term L in the accumulated variables can be ignored. As in the first approach, the density is composited using only length as a weighting factor. From now on, this approach is mentioned as IM (indirect method). The density was estimated for each block and applied on both methods.

Both copper grades estimates for the DM and the GLD, LD, and density estimates were done and properly validated for the Sequeirinho deposit. Before continuing, it is wise to present some aspects considered involving grade estimation.

- Both attributes GLD and LD were estimated using the copper and density variogramas respectively;
- After validating the grade estimates an *in situ* dilution is considered. It is done by considering the block percentage (partial model) intercepted by both the high-grade and the low-grade domain, which is previously codified on each block. These domains consist of a solid ore model. The dilution is done by weighting each block by their estimates and by their both percentages intercepted by each domain and considering the density value for each domain.

After having the estimate grades for both DM and IM including density, a comparison is done between these estimates and the actual short-term estimates through a reconciliation factor (F1) defined as a ratio between the short-term copper average grade and the long-term copper average grade. This comparison comprises data from three production years.

After that, a one-month and a four-month short-term production schedules were proposed and applied to the long-term estimates model. The misclassifications and cost involved in the planed schedule against the short-term actual estimates are analyzed to compare the accuracy of both methods, the direct and indirect one.

Results and Discussion

General Reconciliation

After validating the estimates from both approaches (direct and indirect) and considering the actual grade values from short-term mining planning, the grade reconciliation for three years production was carried out. Figure 1 presents the reconciliation factor (F1) defined as a ratio between the short-term copper average grade and the long-term copper average grade. This figure shows some interesting practical results. For all years the indirect approach predicts better the grade estimated relied for the short-term mining planning. It means that on average the IM predicts the actual grades better than the DM (Table 1 presents the grades related to those years).

These results are closely related to the use of density when compositing and as accumulated variable when estimating. For the three years production a difference on the DM is about 3% related to the actual grade, whereas 1% for the IM. Considering 10.000.000 tons of mined ore per year, the amount of metal that is underestimated in relation to the actual production by the DM is close to 9,000 tons against 3,000 tons underestimated by the IM.

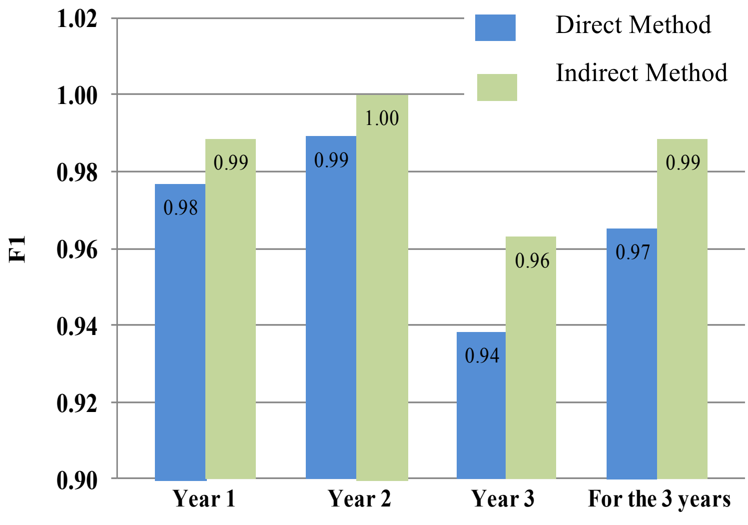


Fig. 1 Reconciliation factors for the year 1, year 2, year 3, and for these three years together.

Table 1 Average grade for the direct and indirect approaches, and for the executed short-term mining planning.

YEAR	IM	DM	ACTUAL GRADES
Year 1	0.85	0.84	0.86
Year 2	0.91	0.9	0.91
Year 3	0.78	0.76	0.81
3 Years	0.85	0.83	0.86

Short-term polygons Reconciliation

Considering that the monthly scheduled production obtained by the short-term mine planning is based on the long-term estimates, the two approaches (DM and IM) are compared to the actual short-term monthly production. The results are presented considering five scenarios picked up from not consecutive months within the three production years mentioned.

The first scenario presents a single blast polygon (BP) selected to be mined out. It is a mix of high grade, low grade and waste blocks. It is shared into three operational polygons (OP) in order to minimize the mine dilution on the loading procedure once the average grade of these operational polygons can differ from the average grade of the entire blast polygon. It process is used to become the loading process more selective. The configuration of this polygon is presented on figure 2. Note that both BP and OP are drawn based on the short-term estimates and then applied to the long-term estimates for both DM and IM.

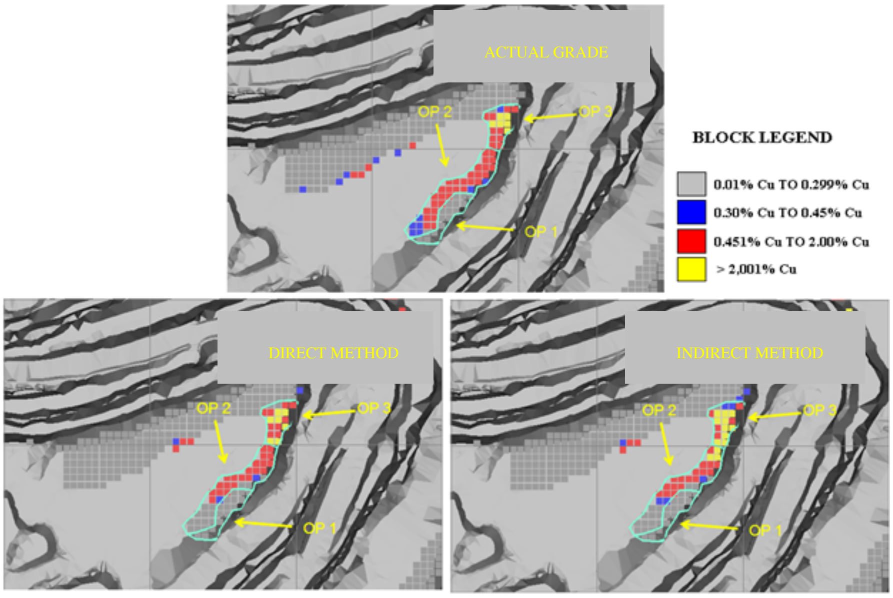


Fig. 2 Polygon selected to be mined out by the short-term schedule in Scenario 1.

Generally, all ore blocks selected by the short-term are also estimated by the long-term, except for some ore missing blocks at the southwestern portion of the OP 2. These missing blocks can be observed in regions not contemplated by the geological model as a mineralized region. That is quite reasonable, once the data used to create the long-term geological model are sparsely collected if compared to the short-term ones. It makes difficult to infer the mineralization contacts in some regions. Note at OP 3 a difference in the block grade patterns among either DM or IM and the actual reference. The reasons for DM and IM estimates differ from the actual grades depend on the representativeness of the information used for long-term estimates (information effect) since this deposit location is considered with high variability and difficult for reaching accurate long-term estimations. Conversely, the difference between DM and IM is possibly related to two main factors: the density influence or the composite length variability.

Table 2 presents the average copper grade of each blast polygon, its respective operational polygons and the difference between both from the actual value. The second part of the table presents the destinations of the blasted material based on an economical cut off grade. Polygons with average grade below 0.3% are sent to the waste pile, between 0.3% and 0.45% to stoke pile and above 0.45 are sent to crusher. Note that only for the operational polygon 1 the planed (DM and MI) does not match the actual executed.

Table 2 Scenario 1 average grades for the blast and operational polygons, the reconciliation factor for the DM and IM from the actual grade.

SCENARIO 1					
	BLAST POLYGON 1				
	OPER. POLYGON 1	OPER. POLYGON 2	OPER. POLYGON 3	BLAST POLYGON 1	REC. FACTOR
DIRECT METHOD GRADE	0.22	1.19	1.68	0.82	92.7%
INDIRECT METHOD GRADE	0.22	1.25	2.11	0.95	106.9%
ACTUAL GRADE	0.37	0.93	1.80	0.89	
DENSITY	2.95	3.13	3.12	3.03	
	MATERIAL DESTINATION				
	OPER. POLYGON 1	OPER. POLYGON 2	OPER. POLYGON 3	BLAST POLYGON 1	
DIRECT METHOD GRADE	WASTE	CRUSHER	CRUSHER	CRUSHER	
INDIRECT METHOD GRADE	WASTE	CRUSHER	CRUSHER	CRUSHER	*******
ACTUAL GRADE	STOCK PILE	CRUSHER	CRUSHER	CRUSHER	

More often than not, both operational and blast polygon were predicted from the long-term date to be sent to the same destination except for the OP 1, which both DM and IM misclassified as waste a material was actually sent to the stock pile. In terms of blast polygon average grade the IM estimates are closer the actual mined grade, overestimating in 6.9% against an underestimating of 7.3% for the DM.

The second scenario (figure 3) presents four blast polygons (BP) not split into operational polygons (OP). It shows a set of three high grade BPs and a waste BP. The BP 2 had its northwestern portion not estimated by both DM and IM. Again, these missing blocks are related to the physical grade control (geological model), which does not contemplate such region. The problem also occurs at the northwestern portion of the BP 1. Both BP 3 and BP 4 were completely estimated. The grade block spatial patterns for the last two BP were similar but both depart from the mined mainly on the blocks where the estimated grade is above 2.00% Cu.

Table 3 presents the average grade for each BP and their destination. The BP 1 estimates by DM and IM point out the same destination of the actual mined. However, for the BP 2 both DM and IM have led the mined material to the stock pile instead of to the crusher (as the actual grades point out). This misclassification is neither related to DM nor to IM estimates but with the poor physical grade control using long term dataset. Both BP 3 and BP 4 have pointed the same destination to mined material as the actual mined grades. The difference between the BP average grades is higher for the BP 2 as expected. For the BP 3 it is practically on target and for BP 4 both methods underestimate the executed grade near to 4%. In each BP both DM and IM equally approximate the actual grades.

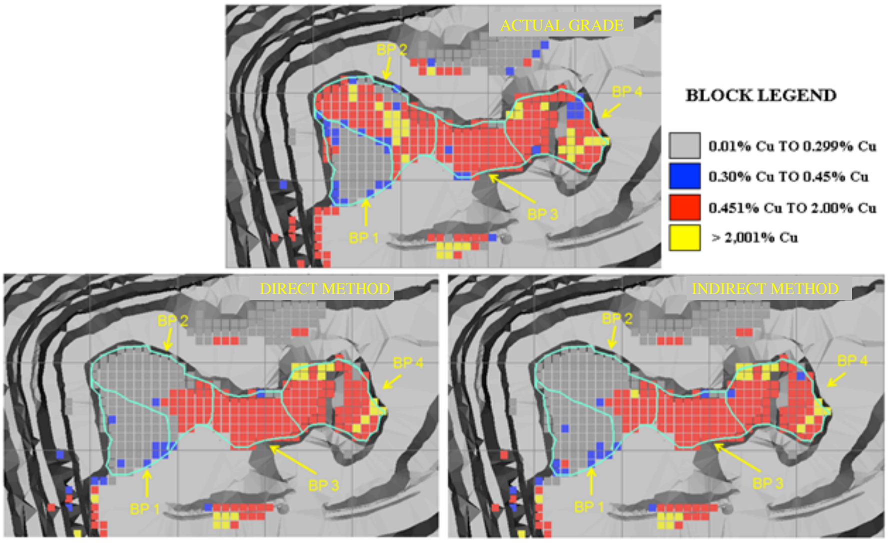
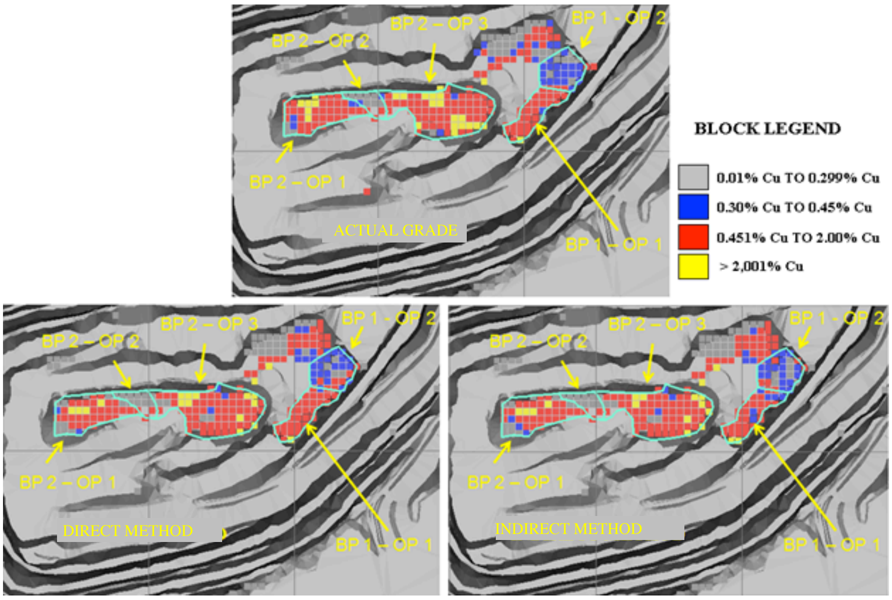


Fig. 3 Polygons selected to be mined by the short-term schedule in Scenario 2.

Table 3 Scenario 2 average grades for the blast polygons and the reconciliation factor for the DM and IM from the actual grades.

	SCENARIO 2	
	BLAST POLY. 1	**REC. FACTOR**
DIRECT METHOD GRADE	0.14	49.6%
INDIRECT METHOD GRADE	0.15	53.6%
ACTUAL GRADE	0.28	
DENSITY	2.77	
	MATERIAL DESTINATION	
DIRECT METHOD GRADE	WASTE	
INDIRECT METHOD GRADE	WASTE	*******
ACTUAL GRADE	WASTE	
	BLAST POLY. 2	**REC. FACTOR**
DIRECT METHOD GRADE	0.35	29.4%
INDIRECT METHOD GRADE	0.34	28.3%
ACTUAL GRADE	1.18	
DENSITY	2.95	
	MATERIAL DESTINATION	
DIRECT METHOD GRADE	STOCK PILE	
INDIRECT METHOD GRADE	STOCK PILE	*******
ACTUAL GRADE	CRUSHER	
	BLAST POLY. 3	**REC. FACTOR**
DIRECT METHOD GRADE	0.84	101.6%
INDIRECT METHOD GRADE	0.84	100.7%
ACTUAL GRADE	0.83	
DENSITY	3.16	
	MATERIAL DESTINATION	
DIRECT METHOD GRADE	CRUSHER	
INDIRECT METHOD GRADE	CRUSHER	*******
ACTUAL GRADE	CRUSHER	
	BLAST POLY. 4	**REC. FACTOR**
DIRECT METHOD GRADE	1.23	95.4%
INDIRECT METHOD GRADE	1.23	95.5%
ACTUAL GRADE	1.29	
DENSITY	2.94	
	MATERIAL DESTINATION	
DIRECT METHOD GRADE	CRUSHER	
INDIRECT METHOD GRADE	CRUSHER	*******
ACTUAL GRADE	CRUSHER	

The third scenario (figure 4) presents two blast polygons. The first one is split into two operational polygons and the second one is split into three operational polygons in order to minimize the dilution during mining.



.**Fig. 4** Polygons selected to be mined by the short-term schedule in Scenario 3.

Table 4 Scenario 3 average grades for the blast polygons and the reconciliation factor for the DM and IM from the executed grade.

SCENARIO 3					
	BLAST POLYGON 1				
	OPER. POLYGON 1	OPER. POLYGON 2		BLAST POLYGON 1	REC. FACTOR
DIRECT METHOD GRADE	0.70	0.37		0.58	112.1%
INDIRECT METHOD GRADE	0.70	0.37		0.58	112.1%
ACTUAL GRADE	0.85	0.36		0.65	
DENSITY	2.92	2.97		2.94	
	MATERIAL DESTINATION				
	OPER. POLYGON 1	OPER. POLYGON 2		BLAST POLYGON 1	
DIRECT METHOD GRADE	CRUSHER	STOCK PILE		CRUSHER	
INDIRECT METHOD GRADE	CRUSHER	STOCK PILE		CRUSHER	*******
ACTUAL GRADE	CRUSHER	STOCK PILE		CRUSHER	
	BLAST POLYGON 2				
	OPER POLYGON 1	OPER POLYGON 2	OPER POLYGON 3	BLAST POLYGON 1	REC. FACTOR
DIRECT METHOD GRADE	0.94	0.68	1.68	1.11	108.71%
INDIRECT METHOD GRADE	0.92	0.71	2.11	1.12	108.03%
ACTUAL GRADE	1.24	0.67	1.80	1.21	
DENSITY	3.14	2.94	3.12	3.00	
	MATERIAL DESTINATION				
	OPER POLYGON 1	OPER POLYGON 2	OPER POLYGON 3	BLAST POLYGON 1	
DIRECT METHOD GRADE	CRUSHER	CRUSHER	CRUSHER	CRUSHER	
INDIRECT METHOD GRADE	CRUSHER	CRUSHER	CRUSHER	CRUSHER	*******
ACTUAL GRADE	CRUSHER	CRUSHER	CRUSHER	CRUSHER	

The BP 1 represents a blast polygon of both high grade and low grade blocks. The pattern of OP 1 is similar to both DM and the actual, but it differs from IM by the inclusion of some low grade blocks. However, on the operational polygon 2 the patterns of DM and IM are different, as well as they are different compared to the actual one. Table 4 shows the destination of these operational polygons coinciding with the actual model. Both methods have overestimated the actual grades by 12%.

The BP 2 constitutes a high grade blasting polygon with the presence of a small number of waste blocks separated on OP 3 to minimize the dilution of these high grade blocks during mining. Except for the OP 2, both OP 1 and OP 3 have presented a different grade pattern between both DM and IM and also when compared to the actual grades pattern. All these operational polygons have no influence of the physical grade control, which means that the difference between these patterns is related to either density or length variability. In all these two operational polygons, the patterns between both DM and IM are similar. Table 4 presents the average grades of these polygons, their destinations and their differences from the actually mined. Note there is no difference between the destinations pointed out by either operational and blast polygon with the actually mined. The BP grades are overestimated by near 8% for both methods.

For the fourth scenario (figure 5) three blast polygons were selected to be mined. These polygons include a large amount of waste disseminated within them. The BP 1 is split into two operational polygons, one of completely waste (OP 2) and another of low grade ore (OP 1). At both the extreme southeastern portion and the western portion of the OP 1 there is no grade estimation for both DM and IM due to the physical grade control (geological model) that did not consider these portions, determining the difference between the two methodologies (DM and IM) and the actual mined. A small difference between the DM and IM patterns actually occurs between these remaining blocks. Looking at table 5, the two methodologies had sent the OP 1 to the stock pile as the actual model. In this case, DM better approximates the average grade executed by4% compared to IM. The OP 2 was sent to the waste for both methodologies and also for the actual model.

The BP 2 was not split but also not all blocks were estimated using DM and IM estimates due to lack of physical grade controlling data the northern portion. This lack of long term information caused a change on the destination of the predicted estimates by both methodologies. In this case, there is no difference on the average grade for these two methodologies (table 5).

The BP 3 is a mix of waste and high grade ore, and as that, it is split into two operational polygons. The OP 1 shows a different grade pattern between both DM and IM, and the actually mined. Between the methodologies there is also a different grade pattern, which could be related to either density or composite length variability. Table 5 shows their similarly to the actually mined, the predicted led the BP to the same destination as the operational polygons. The average grade difference shows a better reconciliation of the IM, which overestimates the actual grade by 4% against 6% overestimated by the DM.

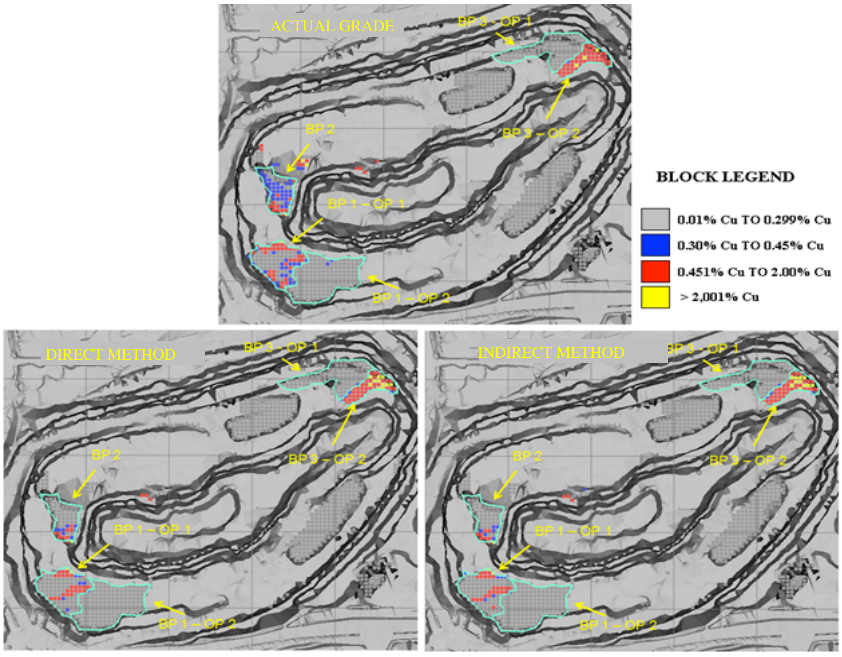


Fig. 5 Polygons selected to be mined by the short-term schedule in the scenario 4.

Table 5 Scenario 4 average grades for the blast polygons and the difference between the DM and IM from the actually mined grade.

SCENARIO 4				
	BLAST POLYGON 1			
	OPER. POLYGON 1	OPER. POLYGON 2	BLAST POLYGON 1	REC. FACTOR
DIRECT METHOD GRADE	0.37	0.02	0.17	70.8%
INDIRECT METHOD GRADE	0.33	0.02	0.16	66.7%
ACTUAL GRADE	0.45	0.08	0.24	
DENSITY	2.93	2.81	2.86	
	MATERIAL DESTINATION			
	OPER. POLYGON 1	OPER. POLYGON 2	BLAST POLYGON 1	
DIRECT METHOD GRADE	STOCK PILE	WASTE	WASTE	
INDIRECT METHOD GRADE	STOCK PILE	WASTE	WASTE	*******
ACTUAL GRADE	STOCK PILE	WASTE	WASTE	
	BLAST POLYGON 2			REC. FACTOR
DIRECT METHOD GRADE	0.22			46.8%
INDIRECT METHOD GRADE	0.22			46.8%
ACTUAL GRADE	0.47			
DENSITY	2.81			
	MATERIAL DESTINATION			
DIRECT METHOD GRADE	WASTE			
INDIRECT METHOD GRADE	WASTE			*******
ACTUAL GRADE	STOCK PILE			
	BLAST POLYGON 3			
	OPER. POLYGON 1	OPER. POLYGON 2	BLAST POLYGON 3	REC. FACTOR
DIRECT METHOD GRADE	0.01	1.40	0.50	106.4%
INDIRECT METHOD GRADE	0.01	1.37	0.49	104.3%
ACTUAL GRADE	0.03	1.36	0.47	
DENSITY	2.80	3.05	2.88	
	MATERIAL DESTINATION			
	OPER. POLYGON 1	OPER. POLYGON 2	BLAST POLYGON 3	
DIRECT METHOD GRADE	WASTE	CRUSHER	CRUSHER	
INDIRECT METHOD GRADE	WASTE	CRUSHER	CRUSHER	*******
ACTUAL GRADE	WASTE	CRUSHER	CRUSHER	

The fifth and last scenario (figure 6) considered four blast polygons to be mined. The BP 1 was not split and it consists of a narrow polygon, which combines waste, low grade and high grade ore. Again, in this situation, the northwestern portion of the polygon was not estimated by the methodologies (DM and IM) due to the absence of geological ore model within this portion in the long-term model. A difference in the southern portion can still be found between the two methodologies and the actually mined. Table 6 shows that the destination predicted by the two methodologies differs, but as in the others scenarios it is not related to the estimated blocks. Even in this situation IM reaches the average grade close to the actually mined.

The BP 2 is a mix of high grade ore and waste. It was split into three operational polygons. Note at the OP 2 a difference between the predicted patterns and the actual one. Table 6 shows its classification and no different in the material destinations were found by both methodologies compared to the actually realized. In this case, DM block grades approximate better the actual average grade.

The BP 3 is a mix of high grade, low grade and waste blocks. It was split into three operational polygons (OP). OP 1 and OP 2 were not totally estimate due to the physical grade control. The OP 3 shows a difference between the predicted and actual block grade patterns mainly for the blocks above 2.001% Cu.

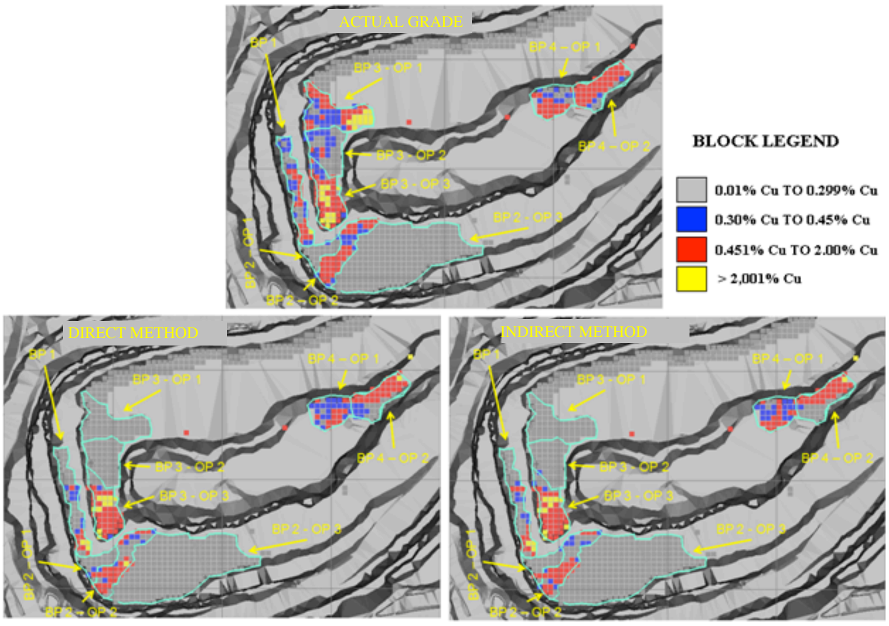


Fig. 6 Polygons selected to be mined by the short-term schedule in the scenario 5.

Table 6 Scenario 5 average grades for the blast polygons and the difference between the DM and IM from the actually mined grades.

SCENARIO 5					
	BLAST POLYGON 1				REC. FACTOR
DM GRADE	0.36				76.6%
INDIRECT METHOD GRADE	0.38				80.9%
ACTUAL GRADE	0.47				
DENSITY	2.88				
	MATERIAL DESTINATION				
DIRECT METHOD GRADE	STOCK PILE				
INDIRECT METHOD GRADE	STOCK PILE				*******
ACTUAL GRADE	CRUSHER				
	BLAST POLYGON 2				
	OPER. POLYGON 1	OPER. POLYGON 2	OPER. POLYGON 3	BLAST POLYGON 2	REC. FACTOR
DIRECT METHOD GRADE	0.14	0.60	0.01	0.11	67.1%
INDIRECT METHOD GRADE	0.14	0.52	0.01	0.10	59.4%
ACTUAL GRADE	0.19	0.76	0.04	0.17	
DENSITY	2.92	2.93	2.79	2.82	
	MATERIAL DESTINATION				
	OPER. POLYGON 1	OPER. POLYGON 2	OPER. POLYGON 3	BLAST POLYGON 2	
DIRECT METHOD GRADE	WASTE	CRUSHER	WASTE	WASTE	
INDIRECT METHOD GRADE	WASTE	CRUSHER	WASTE	WASTE	*******
ACTUAL GRADE	WASTE	CRUSHER	WASTE	WASTE	
	BLAST POLYGON 3				
	OPER. POLYGON 1	OPER. POLYGON 2	OPER. POLYGON 3	BLAST POLYGON 3	REC. FACTOR
DIRECT METHOD GRADE	0.00	0.05	1.32	0.41	44.5%
INDIRECT METHOD GRADE	0.00	0.05	1.31	0.41	44.2%
ACTUAL GRADE	1.07	0.32	1.44	0.92	
DENSITY	2.85	2.74	3.01	2.86	
	MATERIAL DESTINATION				
	OPER. POLYGON 1	OPER. POLYGON 2	OPER. POLYGON 3	BLAST POLYGON 3	
DIRECT METHOD GRADE	WASTE	WASTE	CRUSHER	STOCK PILE	
INDIRECT METHOD GRADE	WASTE	WASTE	CRUSHER	STOCK PILE	*******
ACTUAL GRADE	CRUSHER	STOCK PILE	CRUSHER	CRUSHER	
	BLAST POLYGON 4				
	OPER. POLYGON 1	OPER. POLYGON 2		BLAST POLYGON 4	REC. FACTOR
DIRECT METHOD GRADE	0.47	0.75		0.58	103.6%
INDIRECT METHOD GRADE	0.48	0.71		0.56	100.0%
ACTUAL GRADE	0.47	0.68		0.56	
DENSITY	2.82	3.08		2.97	
	MATERIAL DESTINATION				
	OPER. POLYGON 1	OPER. POLYGON 2		BLAST POLYGON 4	
DIRECT METHOD GRADE	CRUSHER	CRUSHER		CRUSHER	
INDIRECT METHOD GRADE	CRUSHER	CRUSHER		CRUSHER	*******
ACTUAL GRADE	CRUSHER	CRUSHER		CRUSHER	

Table 6 shows that the destination of this operational polygon was the same for both methodologies as well as for the actually mined. The BP 4 is a mix of high grade ore, low grade ore and waste. It was split into two operational polygons. The OP 1 pattern differs between both methodologies and between the mined. Both DM and IM show less high grade blocks than those found on the actually mined blocks. At the OP 2, the DM estimates more low grade blocks and the IM estimates more waste blocks compared to the actually mined. The predictions for the whole blast polygon and the operational ones had the same destination as the mined blocks. The IM average grade of the blast polygon matched the average grade actually mined while the DM model overestimates it by 3.5%.

Conclusion

Two methodologies the direct method (DM) and the indirect method (IM) were applied at grades from a copper deposit to compare their estimates against the mined grades. Grade reconciliation was carried out along three consecutive production years. The indirect method better matches the actual grades for all the three years, as well as for the three years combined production. At the end of these three years, a difference between the mined and the prediction using the direct method was 4% against 1% for the indirect method. This 3% difference represents a significant mass of *in situ* metal content.

At a small scale, these methodologies were compared with several executed blast polygons. It shows that locally the decision about the destinations of the material mined from these polygons have not changed by applying one of these two methods. Some differences were observed but it was not enough to change the destination of these mined materials. However, the polygons average grade obtained by the indirect method usually better matches the mined average grade, which is important to the company goals definition related to the great control and for the quality of the final concentrate product yearly negotiated. The indirect method should be preferably chosen.

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