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Ore control at Peñasquito
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Ore control technological innovations at Goldcorp's Peñasquito Mine

by C.H. Calderon-Arteaga, J. Barrios, M. Almond, R. Ruiz and S. Gering

Located in the northeast corner of Zacatecas State, Mexico, the Peñasquito operation is comprised of the Peñasco and Chile Colorado (Brecha Azul) deposits. Openpit mining (prestripping) began in 2010 and full production commenced during 2011. The openpit mines feed both a sulfide concentrator (mill) and a heap leach pad. The project is owned by Goldcorp Inc. Peñasquito is a poly metallic deposit with Au, Ag, Zn and Pb being recovered as payable metals.

Figure 1

Project location.

As a consequence of lower grade ores expected with advancing mine life, Peñasquito is facing a declining metal production profile. To maximize returns and asset value, plant modifications, including the addition of a carbon prefloat circuit and a pyrite leach circuit to improve recovery, are currently being undertaken. This carbon prefloat circuit will enable the recovery of precious and base metals from carbonaceous sediments. This material is currently being stockpiled. With the associated increase in complexity in the process circuit, the requirement of the ore control system to accurately predict ore feed characteristics is critical to maximizing metal recovery at the Peñasquito operation. The addition of the carbon prefloat circuit was also a key driver in allowing the Chile Colorado openpit to be developed.

These conditions alongside Goldcorp's drive to increase profitability and maximize net asset value has created challenges. These challenges are numerous and multifaceted. However, the ability to accurately route materials from the ore control system is critical to site success, and some of these challenges have been overcome by the adoption and implementation of a new ore control (OC) technology. Examples of these technological innovations in the ore control program are discussed in this article and include improvements in geomodeling, material routing and reconciliation. Successful implementation of these elements has led to significant improvements in selectivity, performance and data management, while reducing the variance between planning and execution, thus helping to drive overall improvement across the operation.

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Project overview

Deposits mined within the Peñasquito operations are examples of breccia pipe deposits formed as a result of intrusion-related hydrothermal activity. The two breccia pipes, Peñasco and Brecha Azul, are the principal hosts for gold-silver-zinc and lead mineralization at Peñasquito. Openpit mining is undertaken using a conventional truck and shovel fleet consisting of 83 haul trucks, five rope shovels and three hydraulic shovels as well as the necessary support equipment. The current Peñasquito processing plant consists of a heap leach gold and silver recovery facility and a sulfide flotation plant.

For this implementation, assay and geology data from blastholes were used in conjunction with MineSight to aggregate the data, perform modeling and evaluate results. MineSight is Hexagon Mining's mine planning software.

Previously, there was an archaic process in place and, although it was working, there were many issues that impacted the reliability of the

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Figure 2

Peñasquito's processing plant and stockpile.

data. This old process was replaced with a newer standardized workflow that allows the users to trust in the results and to make informed decisions with higher confidence.

The goal for this case study is two-fold: to show how technological innovations can lead to improvements in the decision-making process, highlighting the value of using new technologies; and to discuss how technical challenges encountered during the implementations were resolved. This article is targeted at users who want to better manage their ore control process or set up standardized workflows for improving their actual process.

Figure 3

Previous OC process.

Data sources

For this case study, a set of data has been selected over a period of 21 months ranging from January 2016 to July 2017. The previous process and the newly implemented solution were running in parallel for validation purposes from the time of the implementation (August 2016) until the end of the year (December 2016). Data from 2016 corresponds to the results using the previous process, while the remaining data for 2017 correspond to the results of using the new implemented solution.

Blasthole data. A database corresponding to 21 months of blasthole data was used for this case study. Assay and geology information was validated and stored in the drillhole database. The blasthole data inform the OC block model using kriged interpolations.

Block model information. Interpolated data from the OC block model and the long-term planning block are used for this study. OC block model is used to create OC polygons. Polygons are then reported and released to the fleet management system (FMS). OC reserves, as well as the LTP reserves information from the released polygons over a period of 21 months was used for this case study.

Processing plant feed information. Information from the plant feed material entering the processing plant was compiled over the period of study. This information contains tonnage and grade data of material entering the processing plant daily as measured by process control instrumentation and sampling.

About the process

Previous process. The previous process was functioning as expected but some issues were undermining the reliability of the results as well as the understanding of the process by the users. The process used scripts that were running the calculations in the background, so the users were not readily informed about intermediate results or errors. Scripts and workflows could be updated remotely without the final user knowing. So when there was a change, troubleshooting was difficult and sometimes even impossible. Manual calculations and visual interpretation were needed, so the process was prone to errors and therefore consistency across the ore control group was lacking

The process and procedures had already been modified to simplify steps, but the process was

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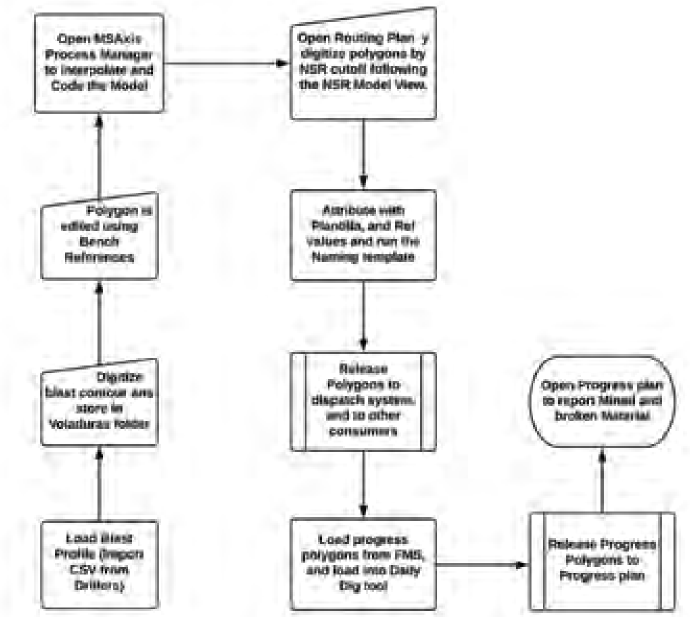
Figure 4

Implemented OC process.



obsolete for the OC requirements.

Steps were required to create and store the OC routing polygons, then a python script was run to specify the area of interest for later usage. After running the script there was a need to run additional MineSight Multiruns to update the OC model. Polygons for OC routing were digitized visually tracing the block model. These polygons were then exported to another department, and they were also being imported into a planning tool to report reserves. OC routing cuts were then exported to feed the FMS. Daily mined polygons were being extracted from the FMS and manually intersected with the OC routing polygons to later import resulting polygons to another instance of the planning tool used to report available reserves.

Technological innovation. A new standardized workflow was implemented to manage the OC process. This new workflow was implemented using MineSight Axis, which offers standardized workflows, is highly configurable and is auditable. With MineSight Axis, a new workflow for Peñasquito's OC was designed and implemented. The new workflow included the usage of different tools that have resolved the issues that the ore controllers were facing using the previous process.

The new process loads a polygon as a boundary and initializes the model, then performs the necessary interpolations and model calculations required to update the model from the assay information.

The next step performs polygon routing, which is done by using MineSight Planner. MineSight Planner integrates the model reserves and routing calculations. It also uses the SQL database to store the OC polygons and related information. This tool uses MineSight Reserves to calculate the reserves information and integrates python calculations, so automatic calculations can be generated. This means that even when creating the OC polygon, the user can recognize the reserves (tonnes and grades) along with the polygon routing options.

Once the OC polygon is created, the user can identify from the automatic reports the corresponding destination for that polygon and then report to other consumers using automatic reporting templates.

Additional calculations are undertaken automatically or by applying a calculation template. These include calculation of material, lithology code, mining phase, tonnes by destination or OC cut name, among others.

The next step in the process is to report to consumers such as surveyors, mine planners or the FMS. To do so, a series of preinstalled template reports can be used. These templates automatically generate the necessary reports. By clicking a single button, these reports are automatically created on the network so the consumers can get them directly without the need for emails or phone calls and to ensure the most up-to-date information is available and used.

The last step is to update the progress with the daily polygons from the FMS and calculate and report broken and available material, including ore grades. Daily mined polygons are exported daily from the FMS, and they represent the daily progress of a shovel. These polygons are then loaded into the MSAxis Daily Dig tool that allows the user to clip the OC polygons with the daily polygons, to generate progress cuts. These progress cuts are stored into a different MineSight Planner plan called Progress, and the progress reports are generated automatically from preinstalled templates. This allows for improved control of material being sent to stockpiles and the process plant.

A reconciliation step was added to the process and is undertaken with the MineSight Axis Reconciliation tool. This tool works by using two reserves setups, one from the exploration model and another from the OC model. These reserves are applied to the resulting solids or polygons from the reconciliation process. The MineSight Axis Reconciliation tool can work

Figure 5

Model update process.

Figure 6

Automatic reporting at creation.

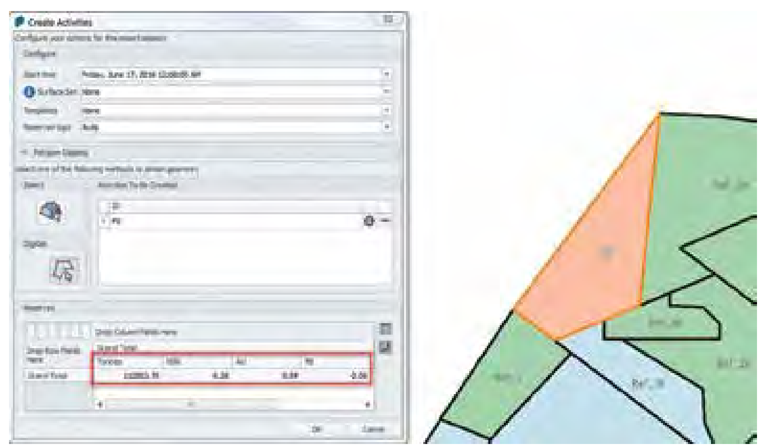
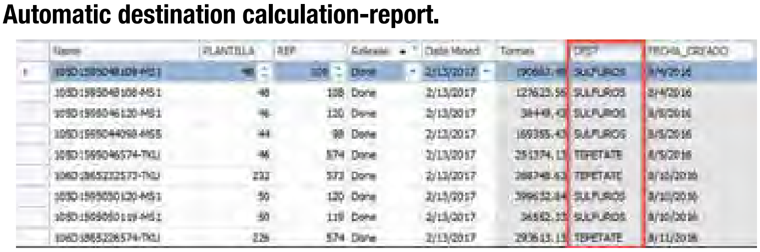


Figure 7

Automatic destination calculation-report.

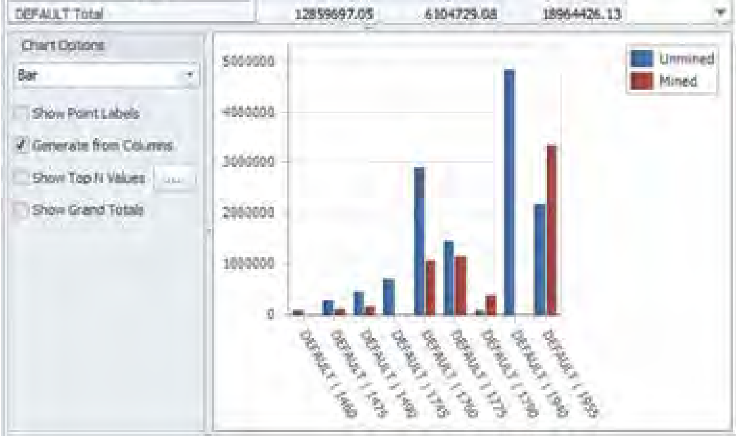


using the "end of period" solid only, the "end of period" solid along with the OC polygons, or just the OC polygons. At Peñasquito, the monthly solid with the OC polygons are used. The tool will then clip the solid against the OC polygons, and the resulting solids are attributed with their corresponding OC polygon, so the result is one set of solids that match the OC polygons and another set of solids that don't match the OC polygons. The user then can report the sections that were mined but not ore-controlled, the sections that were ore-controlled but not mined, and the sections that are in compliance with the

Figure 8

Progress report.

Tonnes		Daily Dig		
DESTINOS	BANCO	Unmined	Mined	Grand Total
DEFAULT	1460	81170.49		81170.49
	1475	260699.14	96946.11	357645.25
	1490	446021.30	140097.30	586118.60
	1745	697377.14		697377.14
	1760	2877654.62	1040470.13	3918124.75
	1775	1432598.74	1130589.15	2563187.89
	1790	62639.94	376355.16	438995.10
	1940	4829047.14		4829047.14
	1955	2172488.54	3320271.24	5492759.78
DEFAULT Total		12859697.05	6104729.08	18964426.13



OC polygons.

Reconciliation reports are created daily to compare the OC reports with the processing plant reports.

During this time period, Peñasquito was also implementing a new BI/BA reporting tool that was successfully integrated with MineSight Axis by creating a table in the SQL database and exporting the necessary information from the routing plan to this table. This allowed the BI/BA reporting tool to get feed from that table through an ODBC connection.

Results of the implementation

As a result of the implemented solution, there were multiple improvements that can be encompassed into three different groups as follows:

- Qualitative improvements.
- Quantitative improvements.
- Collateral improvements.

Qualitative

- Improved understanding of the process. There are no hidden calculations. All the steps are differentiated, documented and well-explained.
- Users have improved visualization of the data. The user can view both blastholes and the model which helps with creation of ore polygons as they can visually identify the materials by colors and cutoffs. This is especially valuable, as the ore control geologists are taking four revenue elements into consideration while still preforming ore cuts.
- Data security has improved by implementing the usage of SQL servers to store OC data, such as routing database, progress database and reconciliation database. Password protection can be implemented, and there is also a record of changes in the process and number of runs for each OC user.
- The process is now automated with automatic calculations from the name of the OC cut to the material calculation using the block model reserves.
- Quick review of the results enables a user to automatically check the results while creating the OC cut. Reports are automatically updated eliminating the need to click buttons and wait for reporting.
- Less training time, as now there is a standard operating procedure for OC where the new users can easily be trained on how to use the system.
- Process is auditable, meaning that the results are repeatable, even after a long period of time, because the implemented solution creates backups of the data along with the project setup, so the results can be reproduced later for audit purposes.
- Easy configuration, as the user can go to a specific step, implement changes, run testing and decide to keep change or not.
- The user is now able to interact with the data to make informed decisions.
- A unique procedure for reconciliation between OC model and long-term model.
- Simplicity and standardization of the process reduces human errors.
- Consistency across the ore control team by following a repeatable process.

Figure 9

Reconciliation report.

Reservas_Recon

Material V...	Reservas ...	MAYO Tonnes	Volume (BCM)	AU	PB	NSR
LEACH	PQREC_OC_003	6,317.32	2,339.74	0.23	0.35	0.00
	PQREC_LP_051	63,122.60	25,473.75	0.55	0.38	0.00
LEACH Total		69,439.92	27,813.49	0.52	0.38	0.00
MILL	PQREC_OC_003	2,448,331.17	919,651.53	0.47	0.26	20.20
	PQREC_LP_051	2,923,206.84	1,092,698.17	0.38	0.21	18.96
MILL Total		5,371,538.01	2,012,349.70	0.42	0.23	19.52
WASTE	PQREC_OC_003	14,930,126.55	5,615,588.29	0.04	0.03	0.93
	PQREC_LP_051	13,888,042.86	5,419,038.99	0.05	0.04	1.26
WASTE Total		28,818,169.41	11,034,627.28	0.05	0.04	1.09
Grand Total		34,259,147.34	13,074,790.47	0.10	0.07	3.98

Quantitative

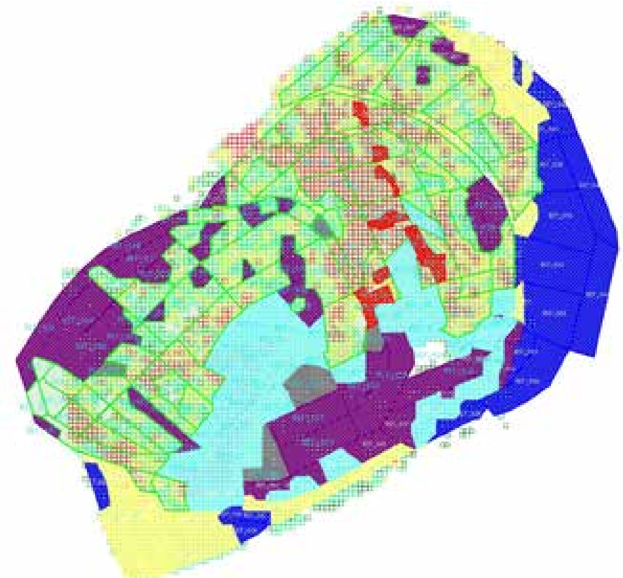
- Fewer number of steps, the previous 16 steps were reduced to 10 steps with the new workflow.
- The new OC process is much faster. The complete processing time per day was reduced by approximately 75 percent from an average of four hours to just one hour.
- Monthly reconciliation processing time was reduced by approximately 80 percent from an average of 10 hours to two hours per reconciliation.
- The reduction in processing time accounts for approximately 1,095 hours per year that ore control geologists have available for alternate value-adding deployment.

Collateral

- Reports to the dispatch system and other departments are now compiled into one file and are released directly to the consumer. This eliminates delays, errors caused by copy and paste and allows for improved sharing of geologic information.
- A new grade variable (carbon) was added to the interpolations by the end users.
- Density calculations have been reconciled between long-term planning and OC models.
- A new pit has commenced with no additional project set-up required.
- A new forecasting report of the available material for the planning department was implemented.
- A SQL table to feed the BI/BA reporting tool with the released cut information was added to the project.
- Automatic material classification was added to the project based on calculations from the block-model information.
- New daily and weekly reconciliation reports are possible now and implemented by the end users. These new daily and weekly reconciliation processes are reconciling the released material from the planning (OC system) with the actual mined material from the execution (as measured by the FMS) that is sent to the processing plant. Results of this reconciliation showed a reduction in the variance of the reported tonnes between the OC system and the FMS of approximately 3.5 percent points, from a value of 5.6 percent in 2016 (previous process) to a value of 2.1 percent in 2017

Figure 10

NSR blocks versus OC polygons.



(implemented solution). This result is a key element for closing the gap between planning and execution.

Technical challenges

Although using the new implemented solution provided many opportunities to standardize and streamline the workflow, challenges occurred during implementation. This included a lack of process knowledge, last minute process changes and long transaction times when querying the blasthole database.

Lack of process knowledge. During the scoping process, it was noticed that there was a lack of process knowledge. Users didn't have a good understanding of what the scripts were doing in the background or how the calculations were performed in order to gain a specific result. This was resolved by reviewing each script one by one, creating a process flow chart and manually calculating the results so we could check the expected results at the end of the calculations.

Figure 11

Chile Colorado Pit.

Last minute changes in the process. During the implementation, it was identified that the results of the implemented solution were not matching the previous process. A small difference was expected due to changes in the reserves engine, but comparing the results from the same inputs, there was a noticeable difference. There was a need to doublecheck the implemented workflow against the previous process and the actual process undertaken prior to the new workflow. Differences between the previous process and the actual process in place were found. There were changes on the scripts calculations, and there was even a new rock type code in the calculations. These differences were preventing the implemented solution from matching the process in place when validating the implemented solution. This was resolved by updating the implemented solution with the new changes in the process. This update came with a corresponding delay in implementation and training.

Long transaction times. Peñasqito's blasthole database holds more than 781,000 blastholes and coordinate fields as well as many other fields like grade fields, that are derived fields comprising best x, y, z, grades. To select the data, the SQL server must calculate the best coordinates and the grades for each hole and then perform the selection. This process took a very long time.

The first option for handling this was to directly use SQL queries. However, the lack of knowledge about database structure and tables made this unfeasible. The second option was to involve acQuire technical support, and the result of working together produced an improved version of the procedure used by MineSight Axis to load the blastholes into MineSight.

Conclusions

The new implemented solution provides a method for standardizing the OC workflow while closing the gap between planning and execution.

After initial implementation, the end users can recognize gaps in the process and implement their own solutions using Minesight Axis software.

The implemented solution led to improvements ranging from improving the quality of the process, passing through time reductions, as well as identifying new ways to use the software to the benefit of the operation, such as identifying the ability to generate new reports or calculations that may improve the end results.

The standardization of the process allowed the users to accommodate new processes with minimal changes in the workflow.

The reduction on the variance of the reported tonnes between the OC system and the FMS shows the importance of the technological innovations in ore control. Technological innovation allows the discovery of existing issues in the process, as well as driving the implementation of new alternatives with plenty of room for improving data processing, calculations, reporting and the decision-making process. ■

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