THE BENEFIT TO OPEN PIT ROCK SLOPE DESIGN OF GEOTECHNICAL DATABASES

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ABSTRACT

Potgietersrust Platinums Ltd is Anglo Platinum's only open pit operation and annually extracts 57 million tonnes of rock from 2 open pits. Over the past 3 years ~220 km of exploration drilling has been done, ~1000 km of rock face have been exposed for face mapping and over 7000 laboratory and field tests have been conducted. This has produced large amounts of geotechnical data to be utilised for feasibility studies, initial slope design and ongoing slope optimisation. It was necessary therefore to develop geotechnical databases to manage the vast amounts of data collected. SABLE and MineMapper 3D databases were created for logging and mapping respectively, with rock testing data incorporated into both. A pit inspections database was developed in MS Access and the existing groundwater and slope monitoring database was improved. The databases were linked to AutoCAD and Datamine to ensure that the latest geotechnical data is used for planning, draughting and modelling. The use of geotechnical databases ensures that no data is lost, standards are maintained and analysis can be easily performed. This increases the confidence of the analysis and allows the geotechnical engineers to optimise slope designs and blast designs on a regular basis. This reduces the risk of slope failure thus making the open pits more economical and safe.

1. INTRODUCTION

Potgietersrust Platinums Ltd (PPRust) is Anglo Platinum's only open pit operation. It is located 35 km north of Mokopane (previously Potgietersrus), in the Limpopo Province of South Africa. It is situated in the centre of the northern limb of the Bushveld Complex, a saucer-shaped layered igneous complex. The northern limb hosts the Platreef orebody, which is a ~100 m thick tabular body that strikes north-south, dips 45° to the west and reaches a depth of at least 1200 m (Figure 1). The Platreef is a PGM deposit and contains economic quantities of platinum, palladium, rhodium, gold, silver, copper, cobalt and nickel, which are all extracted and processed at PPRust.

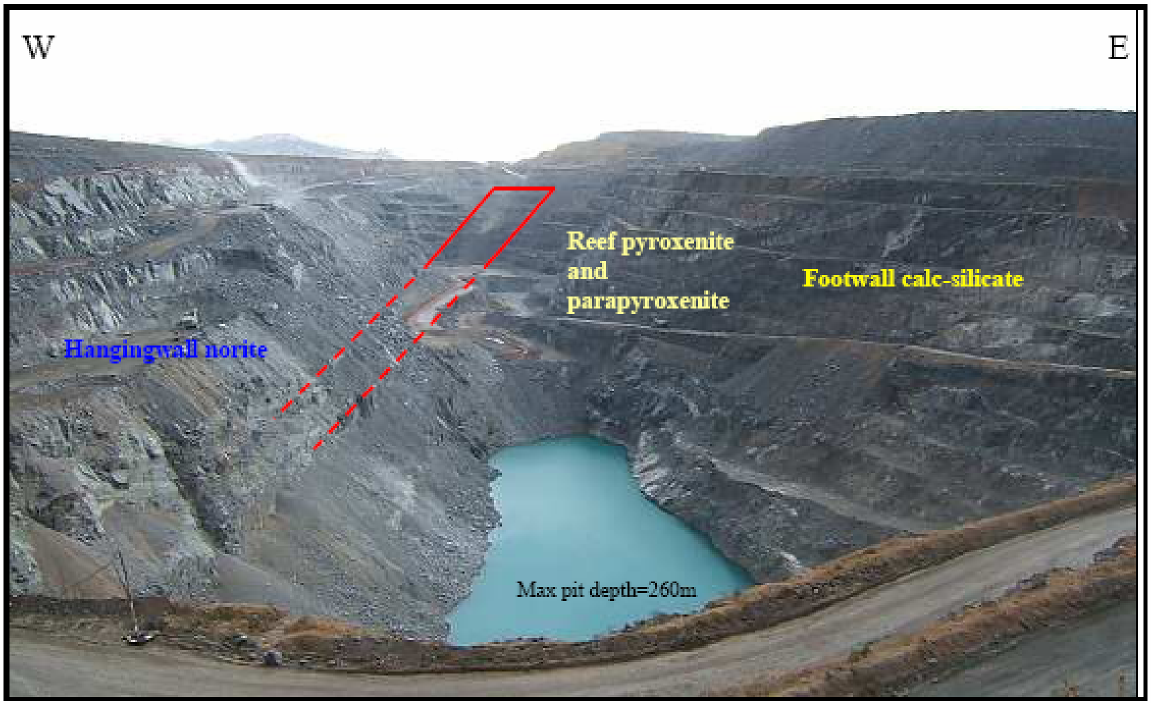


Figure 1 Platreef geology in Sandsloot open pit

Sandsloot open pit opened in 1992 and is currently 2 km long, 600 m wide and 260 m deep. It is expected to operate until 2009 when it will reach a final depth of 300 m. In August 2002 a second open pit, Zwartfontein South, started up 1 km north of Sandsloot. It is 1 km long, 400 m wide and 100 m deep and has a life of mine of 20 years. Together the 2 pits annually produce 57 million tonnes of rock and 4.8 million tonnes of ore. Sandsloot is currently on its 4th and 5th cutback while Zwartfontein is on its 2nd and 3rd cutback. A third open pit, Overysel, is due to begin operations in early 2006 and has a life of mine of over 90 years. There is the possibility of 2 further pits, Tweefontein North and Tweefontein Hill as shown in Figure 2.

There has therefore been a large amount of exploration work done over the past few years and it will continue in the future. This includes large amounts of geotechnical data which is necessary for feasibility studies,
initial slope design and ongoing slope optimisation. It was necessary therefore to set up geotechnical databases in order to effectively use and manage the data collected. In the last 2 years a logging database was created in SABLE, a mapping database was created in MineMapper and rock testing data was incorporated into both of these databases. Slope monitoring, rainfall and groundwater measurements are stored in a customised MS Access database called SSMON. These databases were linked via a MS Access database which enables a user to locate and query any one of the databases as well as open the graphical displays of the data in the relevant program on the PPRust network.

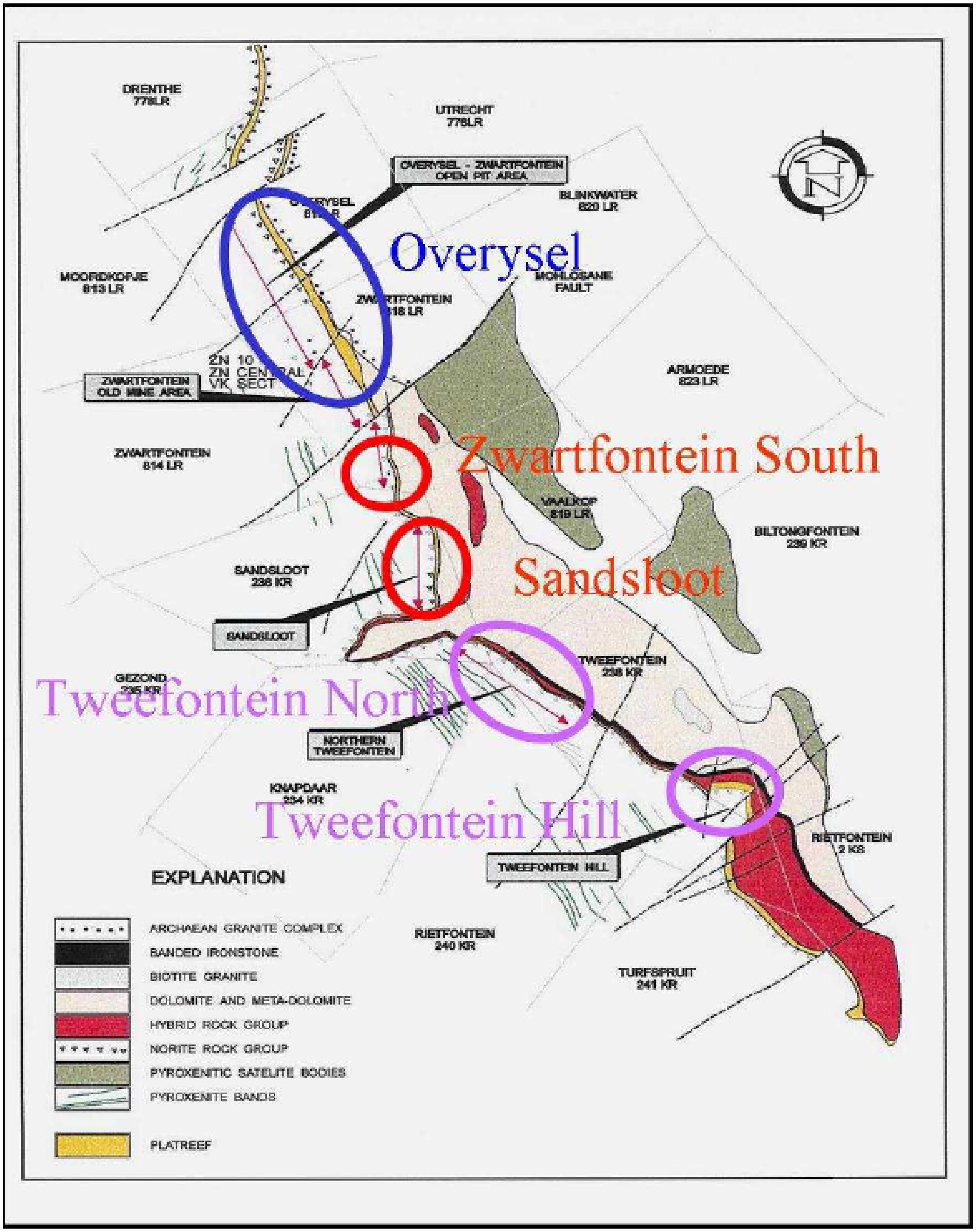


Figure 2 Current and future open pits at PPRust

An inspections database was also created in MS Access for daily pit inspections, detailed pit inspections, hazard mapping and presplit inspections. Links to the databases from AutoCAD, the mine draughting package, and Datamine, the mine modelling package, were created to ensure that the latest geotechnical data is being used for planning, draughting and modelling. The use of geotechnical databases ensures that no data is lost, standards are maintained and analysis can be easily performed. This increases the confidence of the analysis and allows the geotechnical engineers to optimise slope designs and blast designs on a regular basis. This reduces the risk of slope failure thus making the open pits more economical and safe.

2. GEOTECHNICAL FIELD DATA

A large amount of geotechnical field data is collected at PPRust and used for structural and block modelling, failure analysis, blast design and ultimately slope design. The following geotechnical field work is done:

- Geotechnical core logging and face mapping determines rock mass ratings, identifies joint sets and major structures
- Rock testing determines the intact rock strength and elastic properties
- Groundwater studies determine the role of water in slope failure
- Kinematic failure analysis determines the failure mechanism and probability of failure
- Rockfall analysis determines catchment berm design
- 3D modelling predicts rock mass conditions well in advance of blasting
- Presplit analysis audits limit blast design
- Face inspections identify hazardous areas and initiate mitigating actions
- Slope stability monitoring provides early warning of failure
- Risk analysis incorporates all the data to enable management to make the final decision on slope design

In order to standardise, validate and store all this data, databases had to be created. By doing this the data has become more useful and much easier to manage.

2.1 Core Logging

At PPRust, all exploration and in-pit diamond drilling core is logged geotechnically in order to calculate rock mass ratings. Orientated drilling is done as required for the identification of faults, shears and joint sets. The rock mass rating systems used at PPRust are Laubscher's Mining Rock Mass Rating (MRMR) system (1990), Bieniawski's Rock Mass Rating (RMR) system (1976) and Barton *et al*.'s Q system (1974). In the past, Anglo Platinum underground operations used RMR and Q while PPRust used only Laubscher's MRMR. A logging standard was required thus all 3 rock mass rating systems were combined into one log. Some flexibility was maintained to allow for underground and open pit situations. Using a single log instead of 3 separate logs was important for time and cost savings. Using 3 systems provides quality control and auditability and ensures that the standard can be used at all Anglo Platinum operations.

From 2003 to 2005 over 220 km of core has been drilled and logged at PPRust. Previously, logging was done on paper and then manually inputted into Excel where rock mass rating calculations were performed and the data was imported into Datamine. This

was very time consuming, difficult to manage and prone to error thus a database was required. The Anglo Platinum Geology Departments were already using SABLE Data Works, so a geotechnical database in SABLE was developed at PPRust for Anglo Platinum. SABLE uses a table structure for individual logs which sit on different levels in the database. Each table has validation checks, standardized lookups and site specific limits to ensure the data is accurate and usable. The first level in the database is the farm or mine while the boreholes sit on the second level. Each borehole has its deflections (level 3) and each deflection has a number of geological and geotechnical logs (level 4). At PPRust there are 8 geotechnical logs, 5 of them being input logs while the other 3 are automatically generated calculated logs (Figure 3).

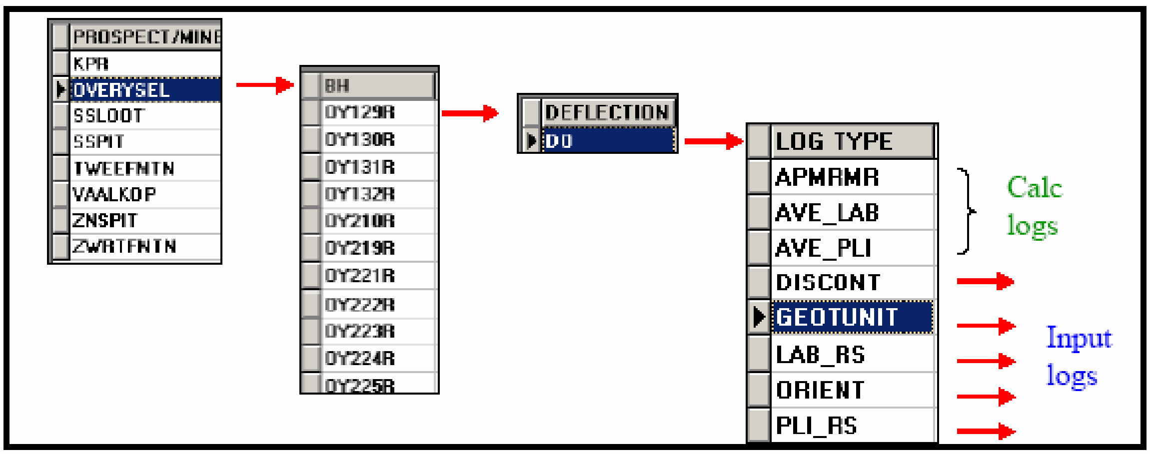
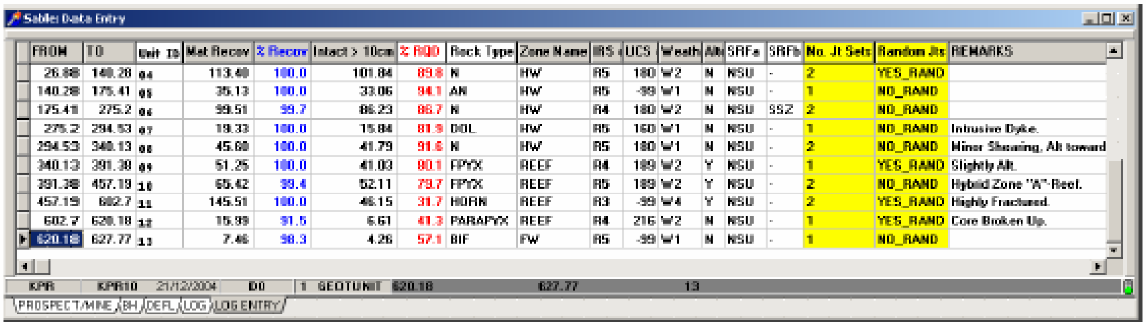


Figure 3 SABLE level structure and geotechnical set up at PPRust

The GEOTUNIT log (Figure 4) contains all the overall geotechnical data for each geotechnical unit in the borehole while the DISCONT log (Figure 5) has all the specific information on each joint set in each geotechnical unit. Point load and lab test results are inputted into the PLI_RS and LAB_RS logs. Orientated drillhole logs are inputted into the ORIENT log in which simplifies the calculations of true dip and dip direction.



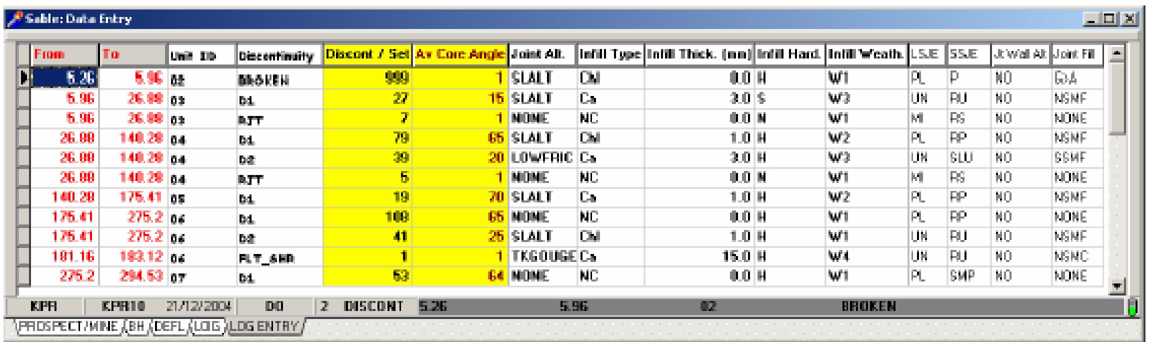
Sable: Data Entry

FROM	TO	Unit ID	Mat Recov	% Recov	Intact > 10cm	% RQD	Rock Type	Zone Name	IRS	UCS	Weath	Alt	SRFa	SRFb	No. Jt Sets	Random Jts	REMARKS
26.88	140.28	04	113.40	100.0	101.84	89.8	N	HW	R5	180	W2	N	NSU	-	2	YES_RAND	
140.28	175.41	05	35.13	100.0	33.06	94.1	AN	HW	R5	-99	W1	N	NSU	-	1	NO_RAND	
175.41	275.2	06	99.51	99.7	86.23	86.7	N	HW	R4	180	W2	N	NSU	SSZ	2	NO_RAND	
275.2	294.53	07	19.33	100.0	15.84	81.9	DOL	HW	R5	160	W1	N	NSU	-	1	NO_RAND	Intrusive Dyke.
294.53	340.13	08	45.60	100.0	41.79	91.6	N	HW	R5	180	W1	N	NSU	-	2	NO_RAND	Minor Shearing, Alt toward
340.13	391.38	09	51.25	100.0	41.03	80.1	FPYX	REEF	R4	189	W2	Y	NSU	-	1	YES_RAND	Slightly Alt.
391.38	457.19	10	65.42	99.4	52.11	79.7	FPYX	REEF	R5	189	W2	Y	NSU	-	2	NO_RAND	Hybrid Zone "A"-Reef.
457.19	602.7	11	145.51	100.0	46.15	31.7	HORN	REEF	R3	-99	W4	Y	NSU	-	2	YES_RAND	Highly Fractured.
602.7	620.18	12	15.99	91.5	6.61	41.3	PARAPYX	REEF	R4	216	W2	N	NSU	-	1	YES_RAND	Core Broken Up.
620.18	627.77	13	7.46	98.3	4.26	57.1	BIF	FW	R5	-99	W1	N	NSU	-	1	NO_RAND	

KPR | KPR10 | 21/12/2004 | D0 | 1 GEOTUNIT | 620.18 | 627.77 | 13

PROSPECT/MINE | BH | DEFL | LOG | LOG ENTRY

Figure 4 GEOTUNIT log in PPRust SABLE geotechnical setup



Sable: Data Entry

From	To	Unit ID	Discontinuity	Discont / Set	Av Core Angle	Joint Alt.	Infill Type	Infill Thick. (mm)	Infill Hard.	Infill Weath.	LSJE	SSJE	Jt Wall Alt	Joint Fill
5.26	5.96	02	BROKEN	999	1	SLALT	CN	0.0	H	W1	PL	P	NO	GOA
5.96	26.88	03	D1	27	15	SLALT	Ca	3.0	S	W3	UN	RU	NO	NSMF
5.96	26.88	03	RJT	7	1	NONE	NC	0.0	H	W1	MI	RS	NO	NONE
26.88	140.28	04	D1	79	65	SLALT	CN	1.0	H	W2	PL	RP	NO	NSMF
26.88	140.28	04	D2	39	20	LOWFRIC	Ca	3.0	H	W3	UN	SLU	NO	SSMF
26.88	140.28	04	RJT	5	1	NONE	NC	0.0	H	W1	MI	RS	NO	NONE
140.28	175.41	05	D1	19	70	SLALT	Ca	1.0	H	W2	PL	RP	NO	NSMF
175.41	275.2	06	D1	108	65	NONE	NC	0.0	H	W1	PL	RP	NO	NONE
175.41	275.2	06	D2	41	25	SLALT	CN	1.0	H	W1	UN	RU	NO	NSMF
181.16	183.12	06	FLT_SHR	1	1	TKGOUGE	Ca	15.0	H	W4	UN	RU	NO	NSMC
275.2	294.53	07	D1	53	64	NONE	NC	0.0	H	W1	PL	SMP	NO	NONE

KPR | KPR10 | 21/12/2004 | D0 | 2 DISCONT | 5.26 | 5.96 | 02 | BROKEN

PROSPECT/MINE | BH | DEFL | LOG | LOG ENTRY

Figure 5 DISCONT log in the PPRust SABLE geotechnical setup

Geotechnical logging data at PPRust is now inputted straight into the SABLE database which is stored on a dedicated server on the PPRust network. This ensures all relevant parties have continual access to the latest data which is daily backed up by the IT department. The logs are validated in SABLE which highlights standard errors, such as overlaps, and allows the user to rapidly rectify the problems. Rock mass rating calculations for all 3 systems are done in SABLE at the touch of a button and the results are stored in a separate log called APMRMR. Average PLI and UCS values for each geotechnical unit are also calculated and stored in AVE_PLI and AVE_LAB logs. The settings for the calculations can be edited by the system administrator or database manager. This person can choose whether to calculate Bieniawski's RMR, Barton's Q and/or Laubscher's RMR and whether the modified versions of each system are required. An MS Access database queries the logs and is linked to Datamine. A graphical log (Figure 6) was also developed in SABLE which provides a quick and easy way of auditing the log. It shows all the raw data as well as the Barton's Q, Bieniawski's RMR and Laubscher's MRMR using both the FF and the JS and RQD method.

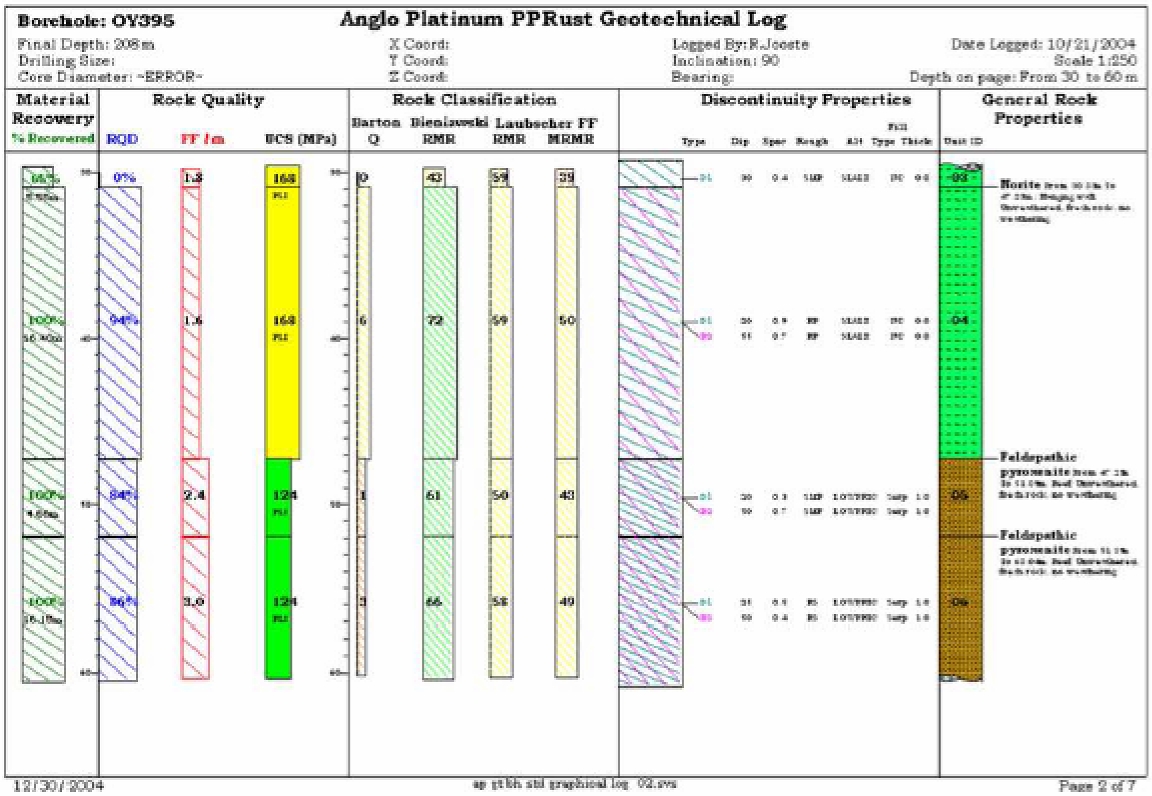


Figure 6 Geotechnical graphical log automatically generated by SABLE

2.2 Face Mapping

The ideal situation in any open pit is that all faces are mapped as soon as they are exposed. With over 400 km of new face exposure every year at PPRust, this is impossible with the current staff quota. The mapping done at PPRust includes both rock mass ratings and line surveys. Previously the data was collected on paper, inputted into Excel where calculations were performed before it was converted to a csv format and exported to Datamine. As with the logging setup, this was time consuming and prone to error. In 2004 MineMapper 3D was introduced at PPRust for geological mapping. As a single database for geology and geotech was preferred, geotechnical mapping input tables were developed in MineMapper 3D. They were designed to match the SABLE logs so that the same data is collected for both logging and mapping and can be used in conjunction for design work.

MineMapper 3D is a database program developed by Century Systems to store and visualise 3D mapping data. The database structure works on a set of maps created for each bench or level (Figure 7). The 3D maps are stored in a central Datamine Fusion database on dedicated network server. The database includes forces validation checks, site specific standards and eliminates most of the human error. After mapping in the pit, the user checks out the relevant map into their local database, adds their data and then checks the updated map back into the central database. In this way no data can be overwritten or lost. Copies of the maps can also be made so individuals can manipulate the data as they choose without affecting the central database. When adding data to a

checked out map, the user imports any relevant survey data and then digitises each facemap's perimeter, contacts, structures and rock mass rating zones. Each object is stored with unique identities in separate tables so that it can be referenced.

A new geotechnical set up in MineMapper 3D was developed at PPRust with 8 tables that mirror the 8 logs developed in SABLE. This includes 5 input tables, namely two rock mass rating tables, a line survey table, a point load table and a lab testing table. Line surveys are the equivalent of orientated logging as they record every joint that crosscuts a face at a certain elevation. Three calculation tables for rock mass ratings, average point load results and average lab test results, are generated at the push of a button. This data is queried by an MS Access database and is exported to Dataminewhere further interpretation and modelling work can be done.

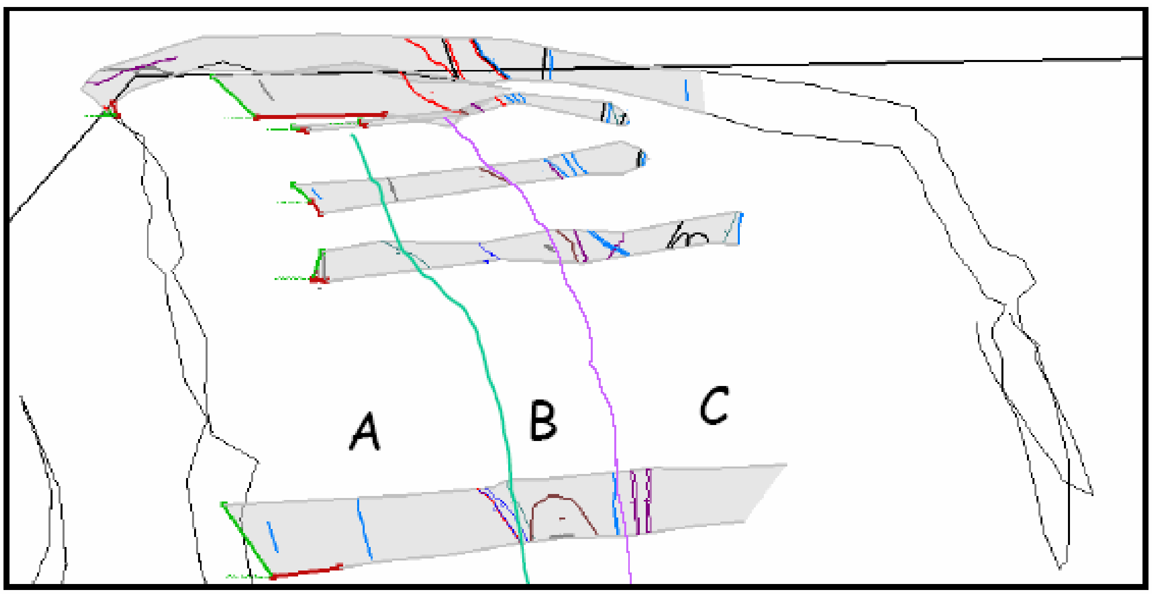


Figure 7 Five facemaps in a MineMapper 3D bench map

Since October 2004, SiroVision digital photogrammetry has been used at PPRust for mapping of dangerous and inaccessible highwalls. Large areas can be quickly mapped and it provides an excellent record of the changes in pit faces over time (Poropat, 2000). Two photographs are taken of the face, a reference point on the face is surveyed and the data is brought into the software where it is converted into a 3D image. The image constitutes a 3D point cloud and a 3D photograph. Dip and dip directions are then measured off the image (Figure 10) and plotted on stereonets. Structures are extrapolated and overlaid over pit designs (Figure 10a) and exported to Datamine. Although SiroVision does not have a database structure, it allows
vast numbers of joints and faults to be measured. This greatly improves joint set identification and kinematic failure analysis (Figure 10b). By careful storage of the data

and a logical, systematic approach used in the data collection process, SiroVision can be optimally utilised.

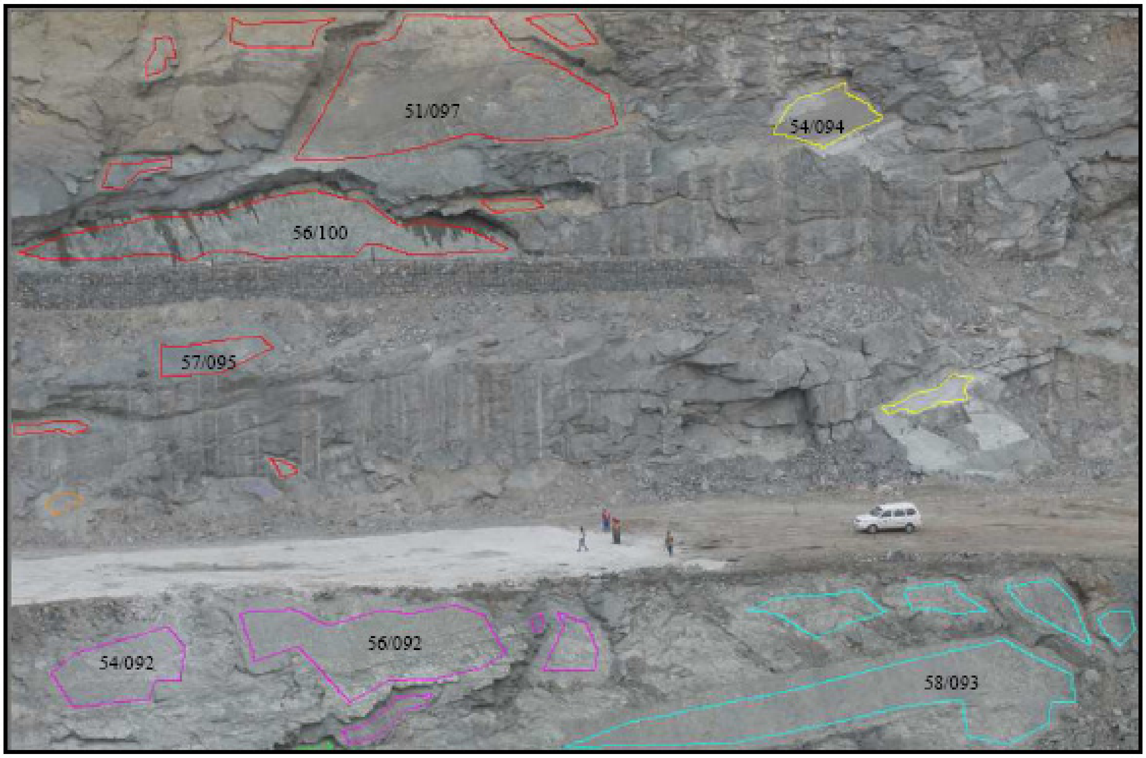


Figure 8 Example of SiroVision mapping with dip and dip directions

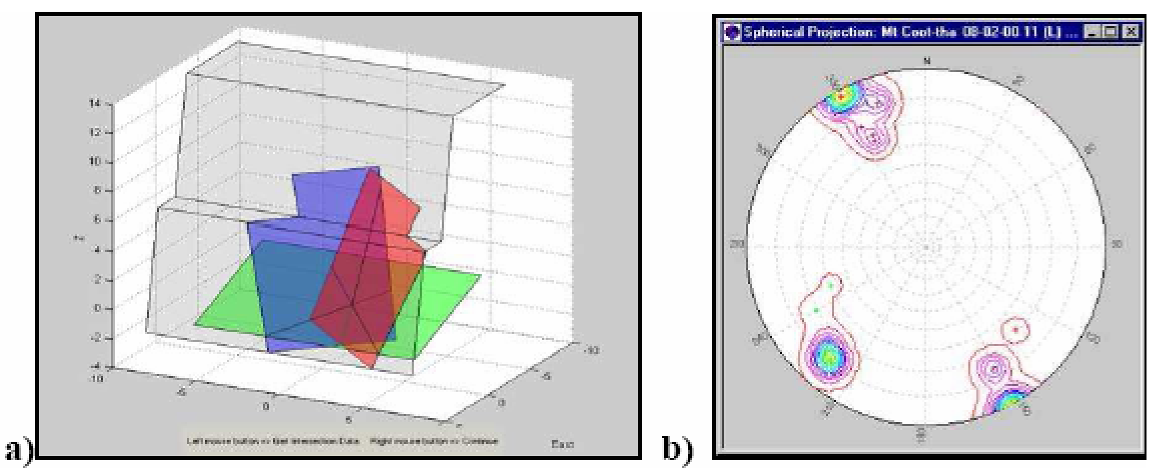


Figure 9 a) Structures overlaid on pit designs and b) stereonets for joint set identification

2.3 Rock Testing

In the last 6 years at PPRust over 10,900 lab and field tests have been commissioned by the geotechnical department. The data has been held in various MS Excel spreadsheets and MS Word and .pdf documents. The data was used for the purpose at the time and then left untouched for many years. This rock testing data has now been included in the SABLE and MineMapper databases to make optimal use of the data.

Intact rock strength plays a large role in rock mass ratings thus a good rock testing database will improve the accuracy of the rock mass ratings. Over the past 6 years 376 UCS tests have been done on PPRust's major rock types. As of January 2005, point load testing is done on all rock types in every logged borehole at PPRust which has resulted in a rapidly growing database of over 9000 tests. The point load values of the major rock types have been compared to the corresponding lab UCS test results and site specific point load factors have been developed. These vary between 22 and 28 which correlates relatively well with the average factor of 20 to 25 (ISRM, 1985). In the SABLE and MineMapper rock mass rating calculations, the best available rock testing data is used. If UCS tests were done on the borehole then they are used. If not then it is likely that point load tests were done and their results are used. If these are also not available then an average UCS for the rock type taken from historical lab testing data is used. For the few rock types that have not been tested, the ISRM intact rock strength field measure is used.

Other lab tests include 138 drillability tests, which were done in order to assist the drilling department in their drill bit selection and budgeting. For slope stability analysis 125 elastic properties tests, 34 Brazilian tensile tests, 16 triaxial tests and 47 shear tests were done. Metallurgical testing, namely 62 Bond work index tests and 82 drop weight tests (DWT), was also done for plant design. This was particularly important in the past few months as the design for the new concentrator at Overysel is underway. All these tests are now in the database and are imported into the geotechnical block model.

2.4 Water and Slope Monitoring

PPRust has a comprehensive slope stability monitoring programme which includes GeoMoS automated prism monitoring, prismless Riegl laser monitoring and GroundProbe radar monitoring. The data from the prism monitoring is automatically stored in a MS Access database called SSMON (Figure 10). It is linked to AutoCAD which displays the movement vectors on cross-sections or 2D plans.

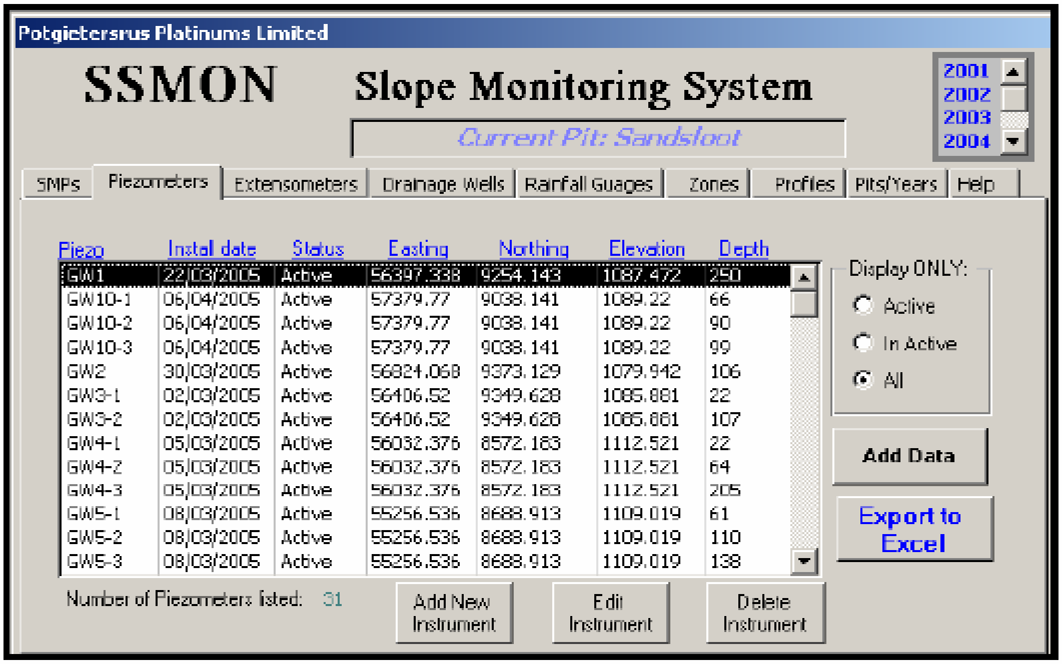


Figure 10 SSMON slope monitoring database front-end

PPRust receives about 500 mm of rainfall a year. The groundwater flow is structurally controlled and does not pose a major slope stability problem but is very difficult to manage. Dewatering methods such as toe drains and pumping have produced poor results and the current strategy at PPRust is to regularly measure the piezometers installed around the pits, to maintain trenches on the pit perimeters and to continue pumping from sumps on lowest bench. Rainfall readings are taken daily and piezometer readings are taken weekly and this data is stored in SSMON. It is also linked to AutoCAD and can be overlaid on slope designs along with the monitoring data. Profiles in all geotechnical zones are setup with the relevant data. This has improved understanding of the nature and deformation of the rock mass thus enabling better predictions of future slope failure.

2.4 FDV and GILS

Often one needs a quick summary of the data stored in all the databases to check when the latest data was added, who added it and whether it has been used yet. To facilitate this, FDV was developed. FDV – Field Data Viewer – is a set of MS Access forms that query the various databases and show the important information on rock testing, logging and mapping. It also has links to the relevant AutoCAD, Datamine and DIPS files. It is particularly useful for managers who do not have time to look at data in detail as well as new staff who are not familiar with the data.

Another MS Access form was set up to navigate through the entire geotechnical folder on the PPRust network. GILS – Geotechnical Information Location System – was developed to allow staff members to quickly locate information and thus save time that is better spent on analysing the data. This I particularly helpful with new staff and for an individuals work that usually gets lost when that staff member leaves. It also has links to all the software programs used by the geotechnical department making the viewing of any document or figure very easy. Each new document is added to the GILS system and is assigned a date, a name, 1 or 2 categories, a project (if relevant), a slope design (if relevant) and any number of keywords. A user can search for a document based on any of these identifiers which is very helpful when looking for old documents. Much time is lost and money wasted on re-analysing data and FDV and GILS aim to prevent that.

3. DATA USAGE

The development of the databases has allowed for optimal utilisation of the geotechnical data, which is used for block modelling, structural modelling, failure analysis, blast design, plant design and slope design.

3.1 Block Modelling

A Datamine script (Figure11) was developed toquickly and easily import the logging, mapping and testing data, calculate certain mining related parameters and view the boreholes and facemaps in 3D. The facemaps are brpought in as horizontal boreholes so that they can be used for interpolation later on. The boreholes and facemaps can be filtered on rock type, RQD, UCS, FF, Q, RMR, MRMR (using FF or JS and RQD) and other mining parameters that will be discussed later on. The boreholes can be easily viewed in 3D with the relevant pit design and any other useful graphics. This makes validation, auditing and interpretation even easier than in the databases themselves.

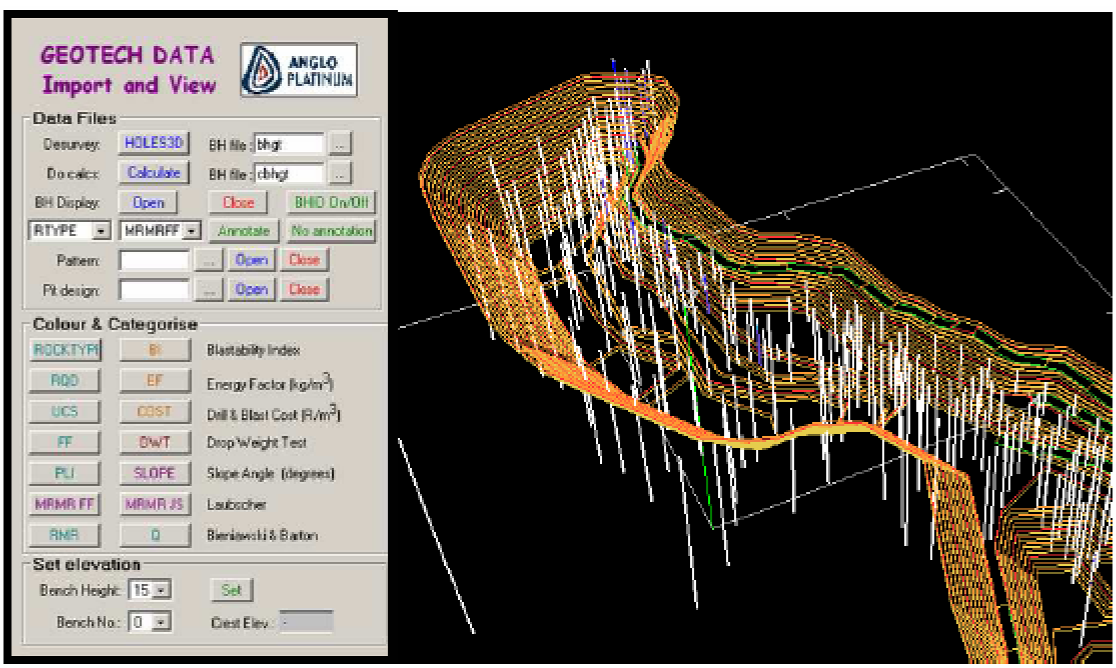


Figure 11 Datamine script developed at PPRust and visual display of boreholes in 3D.

This data is then interpolated into a 3D block model, similar to a geological grade model but in this case each 15 m x 15 m x 15 m block contains geotechnical parameters. A second script (Bye, 2003) was

developed for this which further allows the user to create the block model, interpolate the data, perform calculations and display the model (Figure 12). The optimal slope angle (based on rock mass ratings alone) is calculated using the Laubscher MRMR (using FF) data and Haines and Terbrugge's (1991) slope design chart. Current and future pit designs overlaid on the model and cross-sections are cut through the model. This allows the user to compare the pit design to what the latest geotechnical data predicts is the optimal design (Figure 13). This highlights where slope angles are too steep or too shallow and allows for ongoing slope optimisation. This can result in massive cost savings of the order of hundreds of millions of Rands.

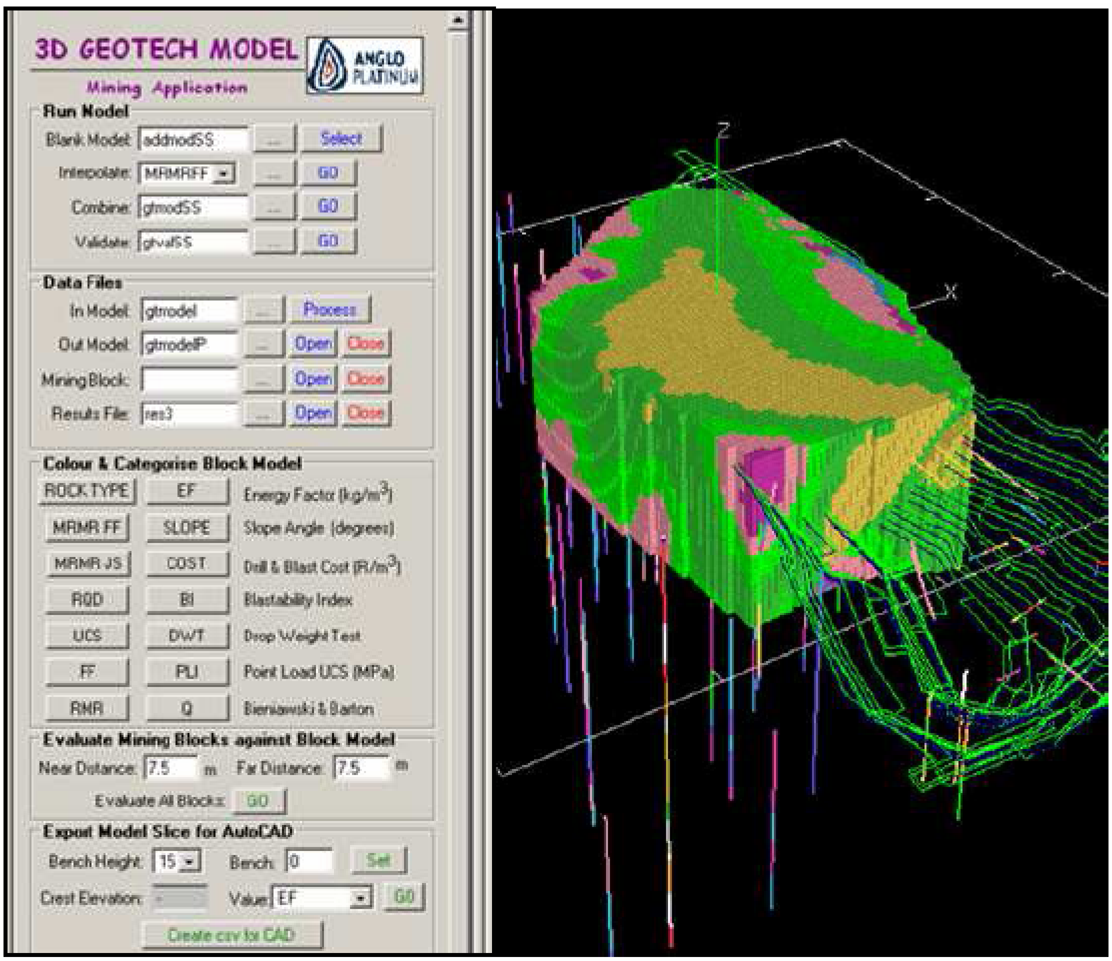


Figure 12 Datamine script and 3D visual of a geotechnical block model and the boreholes used for the interpolation of the model.

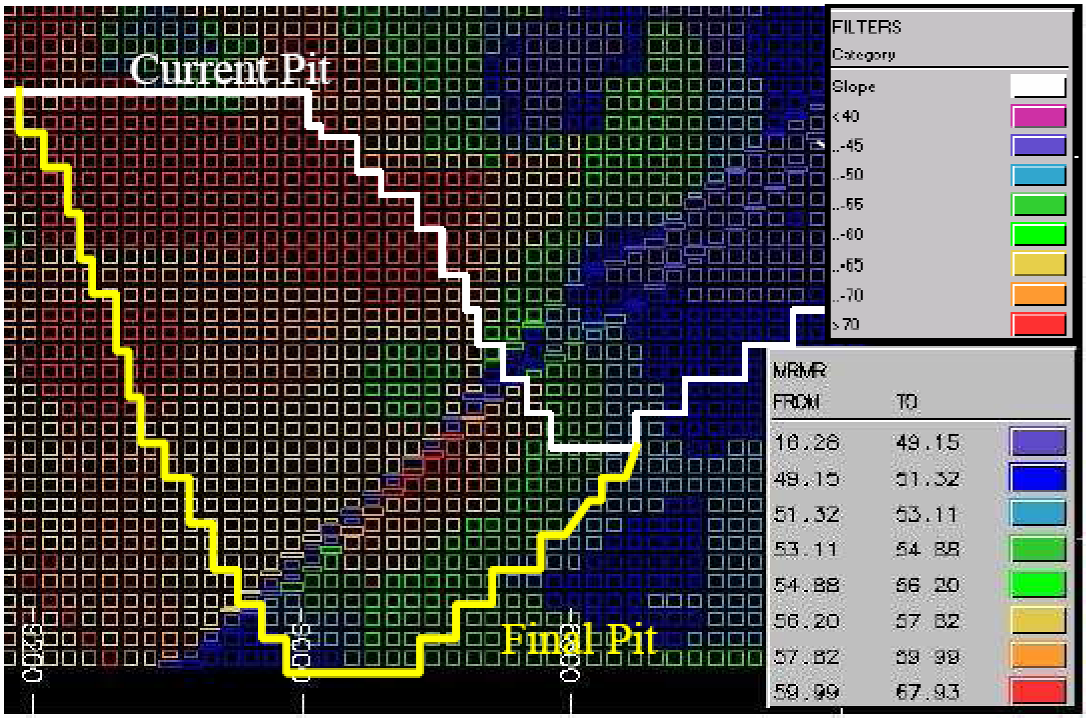


Figure 13 An example of pit designs overlaid on the geotechnical block model with slope angle and MRMR filters

The geotechnical block model is also used for blast design. A blastibility index (Lilly, 1990) is calculated for each block and used in Cunningham's (1986) Kuz-Ram equation together with the mean fragmentation specified by the Processing Plant (ore) and Load and Haul (waste). The required powder factor and energy factor can then be calculated for each block as well as the Drill and Blast cost per block. Thus the geotechnical department provides the Drill and Blast department with the information they need to design an optimal blast on a blast by blast basis.

The third important use of the geotechnical block model is plant design. Based on all the UCS and DWT test results, a conversion from UCS to DWT was developed. A DWT value is now calculated for each block and is now one of the filters in the model script. This information is passed on to the plant manager who can use it to predict the efficiency of the mills for each blast entering the plant.

The geotechnical block model is also used for aiding the Drilling department in drill bit selection and prediction of penetration rates which is based in the UCS of the rock. Apart from the benefit it gives to other departments, the model is used by the Geotechnical department for geotechnical zoning based on rock type, RQD and FF. The rock properties such as cohesion and friction angle, are also included in the model (based on rock type) and used in failure analysis. The model therefore has a wide range of applications which are summarised in the following table.

Table 1 Uses of the geotechnical block model

PARAMETER FILTER	USE
Rock type, FF, RQD	Geotechnical zoning
Rock properties	Failure analysis
MRMR, Slope angle	Slope optimisation
BI/EF	Blast design
Cost	Drill and Blast budget
UCS & elastic properties	Drill bit selection
DWT & elastic properties	Plant design

3.2 Structural Modelling

It is unwise to design slopes purely on rock mass ratings – the structural geology must be taken into account. The orientated drillholes, line surveys, SiroVision mapping, as well as any other structural mapping, are used for structural modelling and kinematic failure analysis. Individual critical structural planes are modelled in Datamine and overlaid on pit designs. In this way they are used to predict areas of potential slope failure. The volume of failure and failure mechanism can also be estimated and predicted in this way. The dip and dip directions of all measured structures are imported into DIPS (Rocscience, 2005) stereonets where failure mechanisms can be identified and an indication of probability of failure can be gained (Figure 14). Using this analysis, geotechnical zones are delineated in each pit and common joint sets and fault zones are identified.

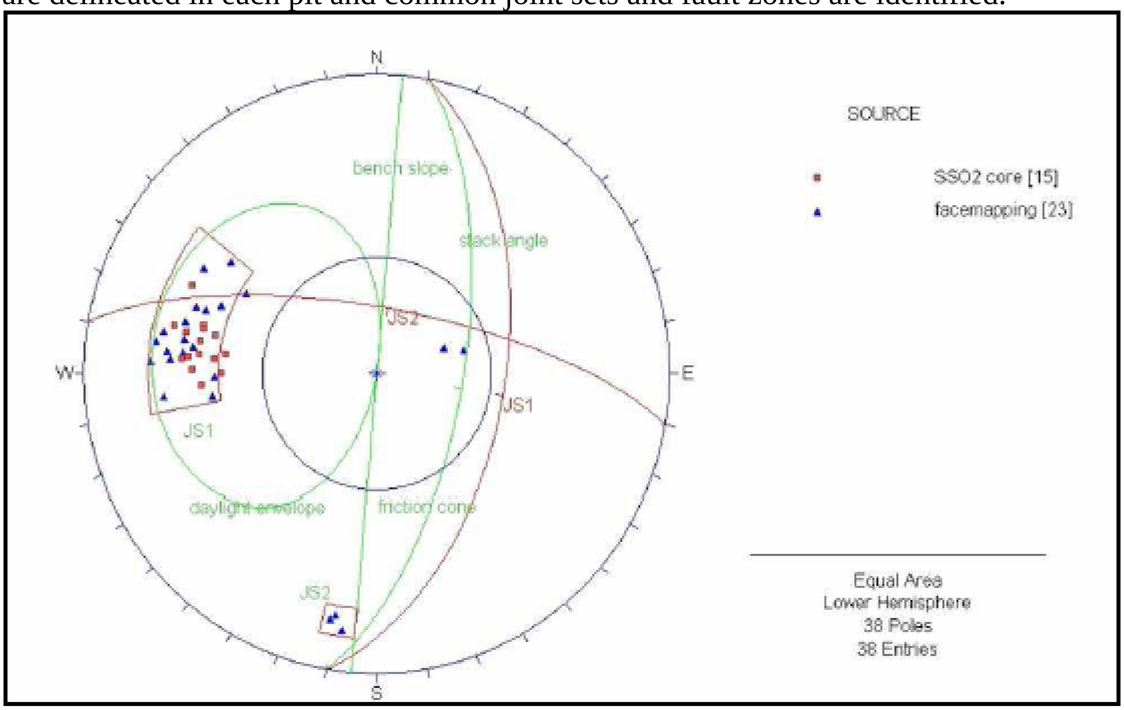


Figure 14 Kinematic failure analysis on a DIPS stereonet, predicting planar failure on the western wall of Sandsloot open pit

2.5 INSPECTIONS

Part of the responsibility of the geotechnical department at PPRust is to perform regular inspections in the open pits. Four different inspections are performed as follows:

- Daily Inspections – performed daily by a geotechnical assistant in all working areas
- Detailed Inspections – performed by a rock engineer after a fall of ground (FOG) or when a Special Area is identified
- Monthly hazard plan inspections – performed by a rock engineer at the end of each month for risk calculations
- Presplit inspections – performed by a geotechnical assistant on all blasted final walls

The data is collected on paper in the field and initially was inputted into MS Excel spreadsheets. In order to manage the data and to make it of optimal use, a database was set up in MS Access. The main form (Figure 15) enables the user to quickly see what inspections have been done where, by whom and on what date. The user can then view or edit any inspection in the database or add a new inspection to the database simply by clicking a button. Each inspection sheet has been converted from MS Excel format to MS Access format reducing the chance of error and speeding up the data capture process. In the future the data will be inputted straight into MS Access in the field using a pocket PC to save time. Emails are sent out to the operations managers when a new inspection is added to the database. They can then open up the database on the network, add their comments and subsequently communicate the observations to their subordinates who implement the risk mitigation recommendations. By storing the inspections in a database the data is secure, auditable, standardised and readily available. This ensures that it is acted upon immediately and people are held accountable.

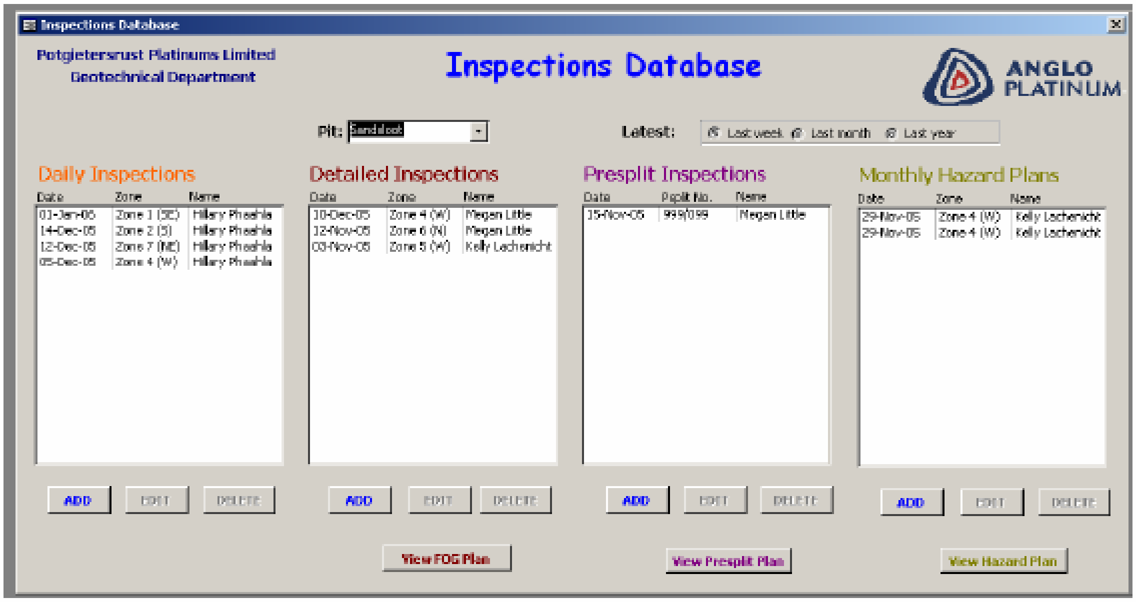


Figure 15 Inspections database main form

The hazard plan inspection is used to determine the risk rating of each area of the pit. All geotechnical factors are taken into account to calculate a risk from 1 to 10. This rating is converted to a risk description and risk colour which is then plotted on the current pit plans to produce a monthly hazard plan for each pit (Figure 16a). These hazard plans are linked to the inspections database thus when emailed, the operations managers can quickly view them and distribute them to their staff. They are displayed in all shift change areas and green areas so that all pit personnel are aware of the dangers in their working place at all times. Each risk rating has an associated action which the pit superintendent is responsible for implementing. The risk ratings are calculated in the MS Access database form by the push of a button thus saving time and avoiding calculation errors. By utilising the database the hazard plans are available on the PPRust network so any of the mine personnel can check up on the hazards in their area.

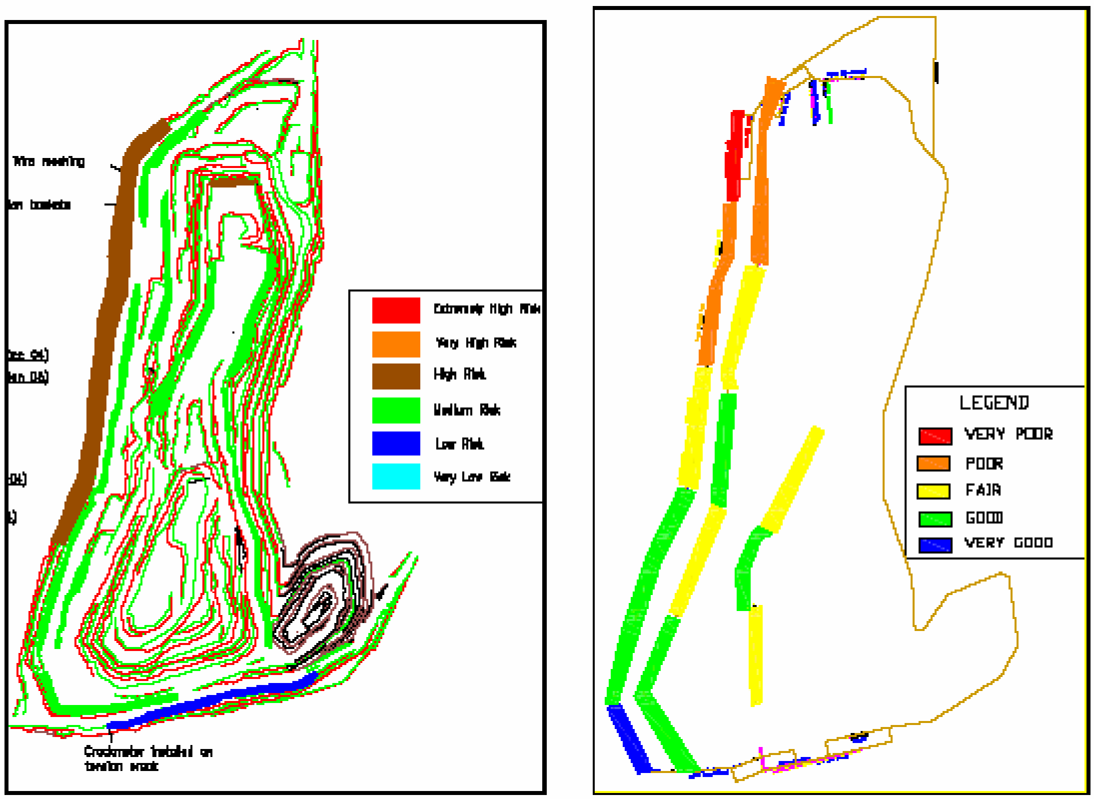


Figure 16 Examples of a) a Hazard plan & b) a Presplit rating bench plan

Presplit inspections were designed to measure the success of the presplit and trim blast designs. They enable the rock engineers and blast engineers to determine the cause of damaged final walls and take remedial action ahead of further blasts. The inspection form in MS Access was set up with calculations at the push of a button which give an overall rating out of 10 for the presplit wall. Those areas with low ratings are investigated. The ratings are automatically overlaid on bench plans in AutoCAD (Figure 16b) which are linked to the database and thus accessible to all mining personnel. Without a database this would not be possible and the inspections would be limited in their usefulness. Human

nature plays a large part in geotechnical risk as regardless of the quality of the systems in place, they are dependant on the people that utilize them. By storing hazard-related data in a database on the network, the risk of miscommunication and lack of awareness is reduced.

5. GEOTECHNICAL RISK

By using the SABLE and MineMapper databases, field data can be validated and modelled within a week of being collected. This allows for a very up to date model and slope designs and blast designs can reassessed on a regular basis. The database also vastly improves the quality of the data as a single logging and mapping standard is used by many geologists and rock engineers. This removes most of the human error and reduces the impact of the high turnover of staff members that is common in the industry.

The database also simplifies the job of the data manager. By being able to view the logs in 3D in their correct spatial location, errors and anomalies can easily be spotted. Corrections can then be made to the logs while the borehole core is still accessible. All of these factors serve to reduce the geotechnical risk inherent in slope design. Slope design is based on a number of parameters which all have a degree of variability. The more data there is available and the higher the confidence in the accuracy of the data, the lower the risk. Anglo American regularly assesses each of its operations on geotechnical risk and the amount of data available, the presence of block models and structural models, and the way in which the data is used, all play a large role in the risk calculation. The improvements made at PPRust in these areas have made a significant contribution to reducing the geotechnical risk and PPRust now has the to the lowest geotechnical risk in the Anglo American group.

6. CONCLUSIONS

Large amounts of geotechnical data are collected at PPRust for feasibility studies, initial slope design and ongoing slope and blast optimisation. It was necessary therefore to set up geotechnical databases to manage the data. A logging database was created in SABLE, a mapping database was created in MineMapper, and rock testing data was incorporated in both of these databases. An inspections database was also created in MS Access for daily pit inspections, detailed pit inspections, hazard mapping and presplit inspections. All these databases were linked via a MS Access database called FDV which enables a user to locate and query any one of the databases as well as open the graphical displays of the data in the relevant program. Links to the databases from AutoCAD and Datamine were created, which ensure that the latest geotechnical data is used for planning, draughting and modelling. By storing all the geotechnical data in databases no data is lost, standards are maintained and analysis can be easily performed. This increases the confidence of the analysis and allows the geotechnical engineers to optimise slope designs and blast designs on a regular basis. This reduces the risk of slope failure thus making the open pits more economical and safe.

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