AEGC Australasian Exploration Geoscience Conference
Brisbane 2023

Identification of dykes using measure while drill data

Lance Karlson
University of Western Australia, BHP
Lance.Karlson@research.uwa.edu.au

Prof Mark Jessell, Prof Myra Keep, Dr Guillaume Pirot
University of Western Australia

Dr Mark Lindsay
University of Western Australia, CSIRO Mineral Resources

Dr Ilnur Minniakhmetov
BHP

SUMMARY

Dykes in the Pilbara region of Western Australia were identified using blast hole measure while drill (MWD) data. This allowed researchers to accurately model the thickness and orientation of dykes in active mining pits, which would otherwise require interpretation from exploration drill holes and pit wall mapping. The findings indicate that geologists can use MWD data to model structural features in mining pits, which in turn has implications for grade control, mine scheduling and geotechnical engineering.

MWD data were obtained using automated blast hole rotary drill rigs with holes spaced between five to nine metres apart. Parameters analysed included rate of penetration, torque, rotary speed, weight on bit and air pressure. Dyke interpretations were validated using high resolution drone scans of pit walls.

Key words: MWD, dykes, structures, Pilbara, iron ore

INTRODUCTION

Accurate modelling of dykes within mining pits is an important but often poorly executed process. Dykes represent significant risks during ore processing, with crushers susceptible to blockages from weathered clay material. Furthermore, the high silica and alumina content of dykes can significantly contaminate ore, leading to lower grade ore and resultant financial penalties for producers (Danaher and Nebel, 2020). Dykes also act as aquatards, causing water table changes (Comte et al., 2017) and in turn having significant implications for mine planning. Similarly, dykes can play an important role in controlling mineralisation (Sheppard et al., 2017), with the potential for ore grades to vary considerably either side of intruded material. Finally, an accurate understanding of dyke orientations has important applications for geotechnical engineers and their assessments of the risk of wall failures.

The metre-scale width of dykes means that they are rarely defined accurately by exploration drilling. As such, mining geologists currently rely on blast hole chemical assays and pit mapping for accurate dyke modelling. However, due to the expense of chemical assays, it is rare for mining geologists to request assays for samples within waste material where dykes may be first encountered during mining. Similarly, pit wall mapping is a labour-intensive process that is often neglected for higher priority production duties. Furthermore, the mapping of production faces exposed within pits – as opposed to final pit walls – represents a safety risk for geologists due to the requirement for interaction with operating mining equipment.

MWD data is recorded by sensors on blast hole drill rigs for analysis and improvement of drill performance, rather than for geological interpretation. The use of this data by mining geologists is therefore an attractive proposition, as no further investment is required to obtain the data. While the concept of using MWD for geological interpretation is not new (Silversides and Melkumyan, 2022), it is rarely utilised by mining geologists because of a lack of confidence in data integrity. The use of equations such as the specific energy of drilling (Teale, 1965) has been attempted as a method to normalise the influence of parameters such as different drill rig operator, drill rig and drill bit. However, these equations are not robust enough to counter the influence of the many other variables involved in drilling. Gaussian techniques have been used with varying success (Silversides and Melkumyan, 2022) however the complexity of these techniques means that they are rarely adopted by mining geologists. In this project, the authors aimed to determine if MWD data demonstrated consistent relationships with dykes such that the data could be used without any normalisation.

MWD DATA PROCESSING

MWD data used in this study was recorded by automated blast hole drill rigs at two Pilbara iron ore mines between January 2018 and October 2022. The lateral spacing of blast holes was between five to nine metres, with hole depths between 12 and 14 metres. Data recorded included drilling rate of penetration, torque, rotations per minute (RPM), weight on bit and air pressure. The data was recorded at 0.25m intervals for each blast hole. The top 0.5m of each hole was removed to prevent erroneous data caused by blasted ground from above benches (Silversides et al., 2020). All negative values for rate of penetration, torque and RPM were removed, as were outlier rate of penetration values over 50m/min and torque values over 50Nm. No data smoothing methods were used in this study in order to provide a clear representation of the potential use of raw MWD data.

CASE STUDY GEOLOGY

The case study analysed in this research is an active iron ore pit approximately 30km from the town on Newman in the Pilbara region of Western Australia. The pit intersects a syncline of Brockman banded iron formation (2492-2451 Ma) within the Hamersley Group. A weathered dolerite dyke intersects the pit along the NW-SE plane of a normal fault (Figure 1). The dyke is approximately 15 m thick, making it difficult to interpret from exploration data. An unmanned aerial vehicle (UAV) was used to capture high resolution scans of the pit walls, allowing validation of MWD data against visible geological features.

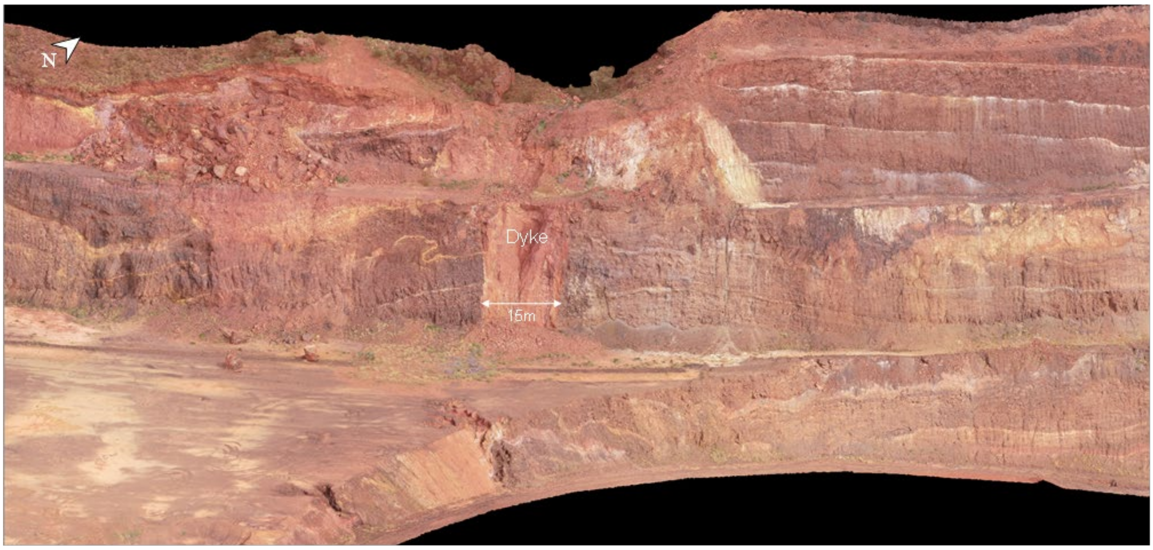
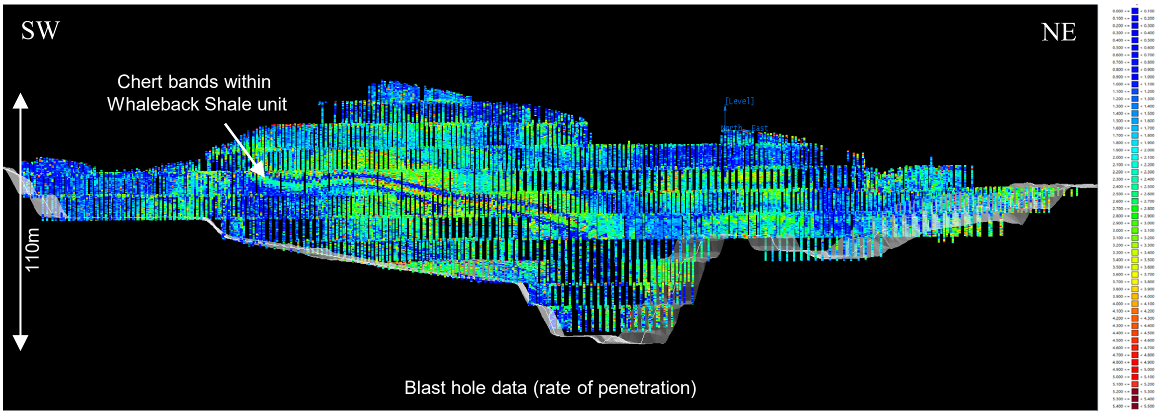


Figure 1: Pit wall scan of case study showing a 15 m wide dyke that intersects the mining pit in a NW-SE orientation

RELATIONSHIP BETWEEN MWD AND LITHOLOGY

11 benches of blast hole MWD data were available for this case study. When viewed in 3D, rate of penetration and torque showed strong relationships with lithology as shown in Figure 2. BIF material is characterised by low penetration rates (dark blue), while shales have higher penetration rates (green). Conversely, torque typically increases in BIF material (green-red) and reduces in softer shale material (light blue). Both datasets show prominent chert bands within the Whaleback Shale unit, which can be used to interpret faults that offset this unit.



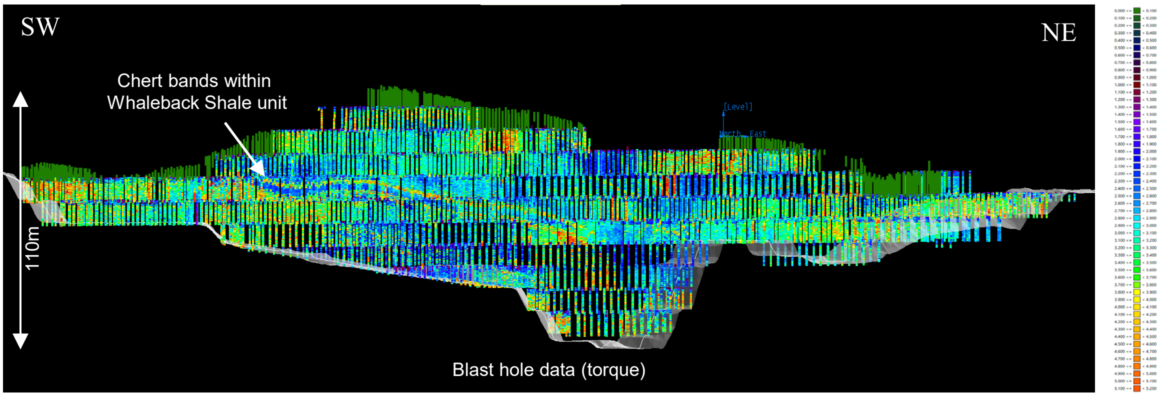


Figure 2. Cross section of a syncline within the case study pit, showing relationships between rate of penetration (top) and torque (bottom) with lithology.

RELATIONSHIP BETWEEN MWD AND DYKE MATERIAL

Figure 3 shows that rates of penetration significantly increase when drilling through the dyke material visible in the pit wall.

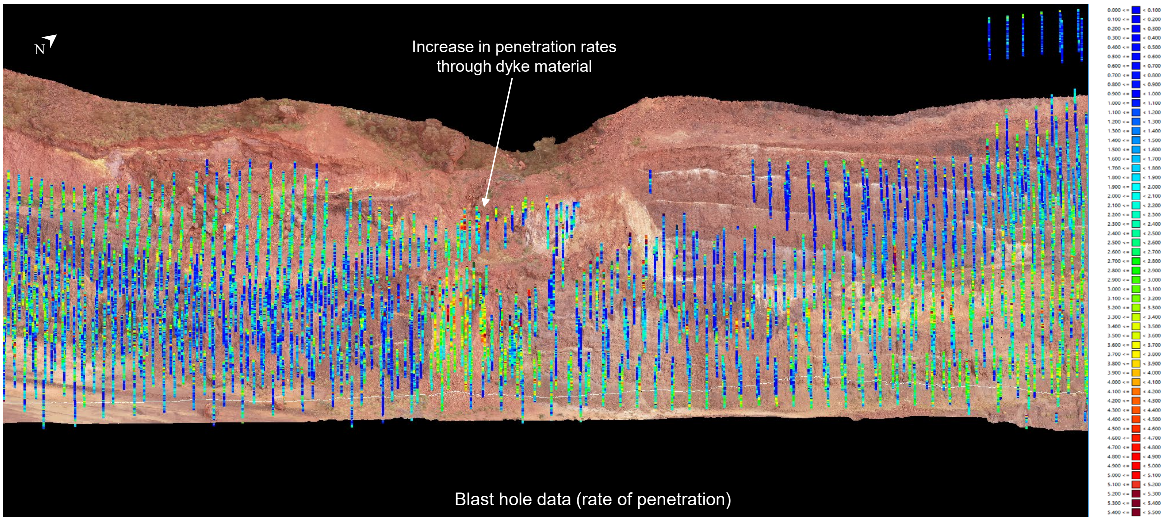


Figure 3. Pit wall scan compared with blast hole rate of penetration data, showing higher penetration rates corresponding with the visible dyke

To better visualise the data, surfaces were generated and coloured by average MWD parameters for blast holes drilled to the same reduced level (RL). These surfaces demonstrate that the dyke can be readily differentiated from surrounding BIF material through higher penetration rates and lower torque.

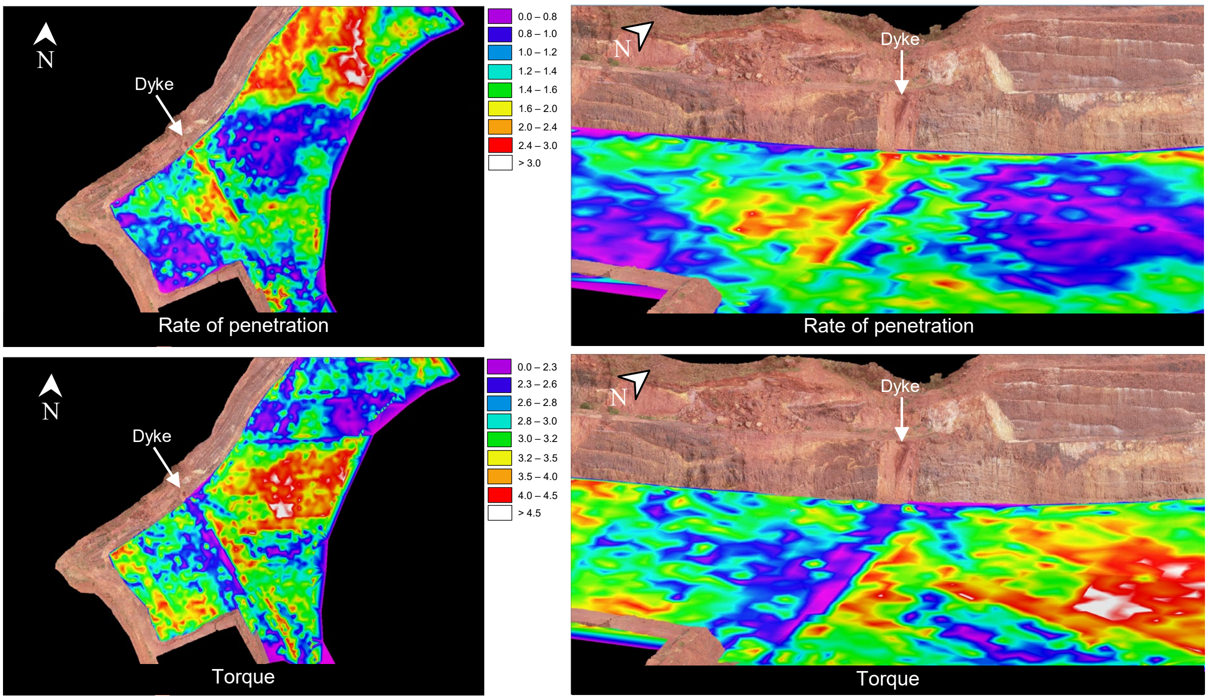


Figure 4. Surfaces coloured by average MWD data for blast holes drilled to the same RL. The surfaces are compared with wall scans where the dyke is visible.

A 3D scatter plot of this data is shown in Figure 5, where ratios of rate of penetration, torque and rotations per minute (RPM) data can be used to differentiate the dyke material from surrounding lithologies.

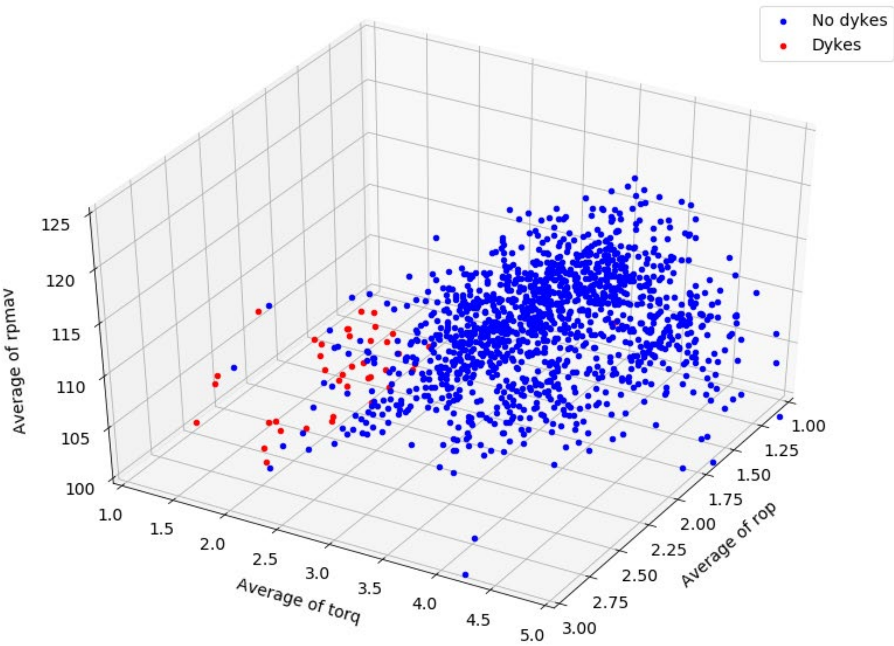


Figure 5. 3D scatter plot showing differentiation of dyke material from surrounding BIF and shale by rate of penetration, torque and RPM. ROP = rate of penetration (metres/minute), Torq = torque (Nm), Rpmav = rotations per minute.

CONCLUSIONS

The aim of this study was to determine if MWD data could be used to identify dykes within mining pits. In the case study shown, it was demonstrated that rates of penetration, torque and RPM could be used to differentiate dyke material from surrounding BIF and shales. This suggests that MWD has significant potential in modelling structural features within mining pits, and supports the potential for further work including the application of machine learning methods to the datasets. The results also suggest that MWD data may be used to reduce uncertainty in geological models, however further work will need to be done to quantify uncertainty changes resulting from this data.

ACKNOWLEDGMENTS

This project was supported by BHP through a research agreement with the University of Western Australia. The authors would also like to recognise assistance provided by Bojan Colak, Myles Ryland and Cameron Leslie from BHP.

REFERENCES

Comte, J. -C., Wilson, C., Ofterdinger, U., & González-Quirós, A., 2017. Effect of volcanic dykes on coastal groundwater flow and saltwater intrusion: A field-scale multiphysics approach and parameter evaluation. Water Resources Research, 53(3), 2171–2198.

Danaher, E., & Nebel, E., 2020. Dolerite-related gibbsite genesis in Australian Banded iron formations. Ore Geology Reviews, 126, 103783–.

Sheppard, S., Krapež, B., Zi, J.-W., Rasmussen, B., & Fletcher, I. R., 2017, Young ores in old rocks: Proterozoic iron mineralisation in Mesoarchean banded iron formation, northern Pilbara Craton, Australia. Ore Geology Reviews, 89, 40–69.

Silversides, K. & Melkumyan, A., 2022. Machine learning for classification of stratified geology from MWD data. Ore Geology Reviews, 142, 104737–.

Silversides, K., Ball, A. and Melkumyan, A., 2020, BIF-hosted deposit unit differentiation using multivariate Gaussian processes on measure while drilling data, Applied Earth Science, 129(4), 164-175.

Teale, R., 1965, The concept of specific energy in rock drilling. International Journal of Rock Mechanics Mining Science, 2, 57-72.