Integrating a Minerals Systems Approach with Machine Learning: A Case Study of 'Modern Minerals Exploration' in the Mt Woods Inlier – northern Gawler Craton, South Australia

Mark Rieuwers
SRK Consulting
L1, 10 Richardson Street, West Perth
mrieuwers@srk.com.au

Antoine Caté
SRK Consulting
S1500, 155 University Avenue, Toronto
acate@srk.com

SUMMARY

There has been extensive exploration in the Mt Woods inlier in the northern Gawler Craton, South Australia since the 1960s, particularly for iron oxide-copper-gold (IOCG) mineralisation since the 1975 super giant Olympic Dam IOCG-U discovery by Western Mining Corporation ~150 km to the SE.

IOCG discoveries in the Gawler Craton have been largely made based on targeted discrete magnetic and/or gravity anomalies since the advent of regional geophysical datasets. Only one significant economic discovery has been made in the Mt Woods inlier – the Prominent Hill metasediment-hosted IOCG deposit in 2001 by Minotaur Resources, with no subsequent economic mineralisation encountered elsewhere in the inlier.

In an effort to accelerate the discovery of a new economic deposit, OZ Minerals opened up more than 2TB of their private geoscience data to external participants as part of the 'Explorer Challenge' competition in early 2019. Once registered, participants had 3 months to use the data provided, along with what was already in the public domain, to attempt to predict where the next mineral deposit in the Mt Woods inlier might be.

Integrating a minerals systems approach with machine learning (ML) has allowed the development of a series of conceptual models for targeting a range of deposit types and commodities. Exploration success based on this modern targeting approach will eventually lead to new suitable exploration strategies to discover the next generation of economic mineral deposits, particularly those concealed under cover.

Key words: exploration, machine learning, mineral systems, targeting, Mt Woods, under cover.

INTRODUCTION

A machine learning (ML) based approach to minerals exploration was applied to a perceived-to-be well explored terrain as part of the 'Explorer Challenge' run by OZ Minerals. The Explorer Challenge involved OZ Minerals opening up more than 2TB of their own private geoscience data from their Mt Woods exploration package in the northern Gawler Craton, South Australia (Figure 1). This package hosts the Prominent Hill iron oxide-copper-gold (IOCG) deposit discovered by Minotaur Resources in 2001. Since Oxiana Resources (who later became OZ Minerals in 2008) acquired Prominent Hill and the associated Mt Woods exploration package in 2004, no economic mineral deposits have been found despite a significant exploration effort. Indeed, exploration in the region dates back to the 1960s with multiple significant campaigns by various companies post the 1975 super giant Olympic Dam IOCG-U discovery by Western Mining Corporation, 150 km to the SE of Prominent Hill.

Historical exploration has largely been focused on the known IOCG deposit model approach – with a strong emphasis on magnetic anomalies and later, on coincident gravity anomalies. This paper summarises the multidisciplinary approach used in the re-interpretation of geoscience datasets across varying scales – integrating a minerals system approach with ML in assisting in the development of new conceptual targets and an exploration strategy to identify concealed economic mineralisation in the region.

LOCAL GEOLOGY

The Gawler Craton hosts widespread iron-oxide copper-gold (IOCG) alteration and mineralisation, including the actively mined Olympic Dam, Prominent Hill and Carrapateena deposits, along with several undeveloped prospects including Wirrda Well, Oak Dam, Acropolis and Emmie Bluff.
The Mt Woods inlier sits within the northern Gawler Craton of South Australia and comprises Palaeo- and Mesoproterozoic metamorphic and igneous rocks. It is characterised by its distinctly high magnetic and gravity signatures and its boundaries are sharp and structurally controlled (Freeman & Tomkinson, 2010).

The Mt Woods inlier is predominantly composed of ca. 1760-1740 Ma Palaeoproterozoic metasedimentary and metavolcanic rocks that underwent one or more amphibolite to granulite facies metamorphic events. The inlier is multiply deformed and been exposed to at least two phases of magmatism along with a late episode of Neoproterozoic mafic dyke intrusion (Gairdner Dolerite). Nine basement subdomains have been defined (e.g. Freeman & Tomkinson, 2010).

Outcrop in the Mt Woods inlier is rare with flat-lying Phanerozoic cover of up to 400m in thickness, unconformably overlaying the Proterozoic basement – however, the paleo-topography of the basement could be up to pre-Neoproterozoic in age (Freeman & Tomkinson, 2010). This undulating basement topography is notorious for confusing any interpretation of the gravity data in particular, including resulting in false positives for high density anomalies – some which have been subjected to exploration testing.

The Prominent Hill deposit sits on the southern margin of the Mt Woods inlier and comprises the Malu (open pit) and Ankata (underground) orebodies. It developed proximal to a major fault separating the Neptune and Blue Duck sub-domains (Freeman & Tomkinson, 2010). Mineralisation comprises disseminated chalcocite, bornite and chalcopyrite in the matrix and clasts of hematite-rich breccias (Belperio et al., 2007). Several episodes of hematite alteration (+ sericite, clay minerals, chlorite) and brecciation have overprinted the host rocks, focused by a sequence of northerly dipping breccias. Magnetite is absent in the mineralised breccias but is present as a poorly mineralised massive magnetite (+ pyrite, actinolite, phlogopite, chlorite, serpentinite, carbonate, talc) 'skarn' to the north of the Hangingwall Fault Zone to the deposit.

The iron oxide alteration associated with the deposit defines a discrete gravity anomaly associated with a coincident, but offset from, magnetic anomaly related to the 'magnetite skarn'. The source of the gravity anomaly is hematite alteration associated with mineralisation and is accentuated by a palaeotopographic high.

Other hematite-rich prospects in the Mt Woods inlier include Triton, Proteus, Caliban, Peculiar Knob and Manxman B while magnetite-rich prospects include Neptune, Joe's Dam, Manxman A1 and Taurus.

MINERAL SYSTEMS APPROACH TO EXPLORATION TARGETING

Since the discovery of Olympic Dam, the eastern Gawler Craton has been known to be highly prospective for IOCG systems, despite the true nature of their formation being poorly understood at that time. Despite significant advances in the understanding of the deposit models since, exploration success has been rare and difficult. In the Mt Woods inlier, Prominent Hill has so far been the only economic discovery.

Much less research effort and exploration dollars have been spent on other mineral systems in the region. A mineral systems approach (e.g. Wyborn et al., 1994; Kreuzer et al., 2008; McCuaig et al., 2010; McCuaig & Hronsky, 2014) essentially reduces the critical parameters of ore formation to: (1) source of energy to drive the system, (2) source of fluids, metals and ligands, (3) pathways along which fluid flow can be accommodated to trap sites, (4) trap sites along which fluid flow becomes focussed and its composition or conditions modified, and (5) outflow zones for discharge of residual fluids (Figure 2).
This process-based approach to targeting is unrestricted and allows for the exploration of not only IOCG systems, known to occur in the area of interest, but also not excluding other examples such as iron sulfide-copper-gold (ISCG), Broken Hill Type (BHT) and Intrusion-related gold systems (IRGS) – not yet known to economically occur in the area of interest.

Specific features that are considered important to the formation of these type of mineral systems include (e.g. van der Wielen et al., 2013): (1) melting of metasomatized mantle and resultant emplacement of mafic bodies (Hayward & Skirrow, 2010); (2) meteoric water infiltration of a rift package containing extensive evaporates producing dense oxide saline brine allowing the stripping of metals (Bastrokov et al., 2007) and (3) a change in redox conditions (Williams et al., 2010). Temperature, pH and ligands may play a role in certain deposits (Bastrokov et al., 2007).

Combining this approach with ML allows for efficient assessment of mineral potential and prospectivity over large areas and datasets.

MACHINE LEARNING INTEGRATION TO EXPLORATION TARGETING

Machine learning (ML) is a highly valuable set of tools to interpolate information or data from other datasets. In environments with sparse data, machine learning can be used either directly for prospectivity mapping by training an algorithm on known occurrences and available data or indirectly for the interpolation of specific geological information. For example, an algorithm can be trained to recognise the geophysical signature of a specific type of intrusion or alteration and map these intrusions in areas with poor outcrop exposure. In any case, such methods have to be combined with strong domain expertise to obtain meaningful results, and the validation of these results on testing data is necessary.

Several datasets covering the Mt Woods inlier were used in regional and local interpretation scales and fed into the ML based targeting approach. These included geological and structural mapping, aeromagnetics and gravity, drill hole assays and lithology, hyperspectral, radiometric and elevation datasets. Structural interpretation of the 2D seismic datasets provided was also undertaken, which was incorporated into 3D modelling (in Leapfrog) in localised drill hole rich areas. The drill hole density was not sufficient regionally to generate a single meaningful regional 3D model. The aim of the local 3D modelling was to better understand the geometry and possible controls on the known IOCG mineralisation at a local scale to assist with extrapolating out to regional scale targeting.

Structural and lithological complexity was also fed into the ML exercise using a GIS-based automated lineament analysis toolset. Geochronological datasets were added in as an extra layer of constraints to the geological and structural interpretations and were also incorporated into the ML stage.
The area of interest for data used in the exercise was expanded well beyond the immediate Explorer Challenge area. This was to allow the ML enough learning points with known economic mineralisation. The area selected for the exercise incorporated the proven most prospective parts of the Gawler Craton Olympic Domain to date – i.e. from the Mt Woods OZ Minerals tenement package in the northwest down to and including the Punt Hill prospect in the southeast.

CONCLUSIONS

ML integrated with a minerals systems approach to targeting allows the use of a wide range of geoscience datasets to be used efficiently in developing new conceptual mineral exploration targets, including in perceived-to-be well explored terrains.
Several new conceptual exploration targets resulted from this approach during the Explorer Challenge exercise conducted by SRK Consulting – and were not limited to known economic mineralisation styles or locations within the Mt Woods inlier.

ACKNOWLEDGEMENTS

SRK Consulting would like to thank OZ Minerals, in particular it's exploration team, for providing valuable guidance for all of the participants of the Explorer Challenge.

DIMAP assisted SRK Consulting with provision of a fixed-wing spectral data set and its processing and interpretation. This work was a collaborative effort across various SRK Consulting offices, bringing together exploration expertise from Perth, Melbourne, Toronto, Vancouver and Cardiff.

REFERENCES

Bastrokov, E.N., Skirrow, R.G., Davidson, G.J., 2007. Fluid Evolutiion and Origins of Iron Oxide Cu-Au Prospects in Olympic Dam District, Gawler Craton, South Australia. Economic Geology, 102, 1415-1440.

Belperio, A. Flint, R. Freeman, H., 2007. Prominent Hill: A Hematite-Dominanted, Iron Oxide Cu-Au System. Economic Geology, 102, 1499-1510.

Freeman, H., Tomkinison M., 2010. Geological setting of iron oxide related mineralisation in the southern Mount Woods Domain, South Australia, In: Porter, T.M (Eds), Hydrothermal Iron Oxide Copper-Gold and Related Deposits: A Global Perspective on Advances in the Understanding of IOCG Deposits,. PGC Publishing, 3, 171-190.

Kreuzer, O.P., Etheridhe, M.A., Guj, P., McMahon, M.E., Holden, D.J., 2008. Linking Mineral Deposit Models to Quantitative Risk Analysis and Decision-Making in Exploration. Economic Geology, 103, 829-850.

McCuaig, T.C., Beresford, S., Hronsky, J., 2010. Translating the mineral systems approach into an effective exploration targeting system. Ore Geology Reviews, 38, 128-138.

McCuaig, T.C., Hronsky, J., 2014. The Mineral System Concept: The Key to Exploration Targeting. Society of Economic Geologists Special Publication 18, 153-175.

van der Wielen, S., Fabris, A., Keeling, J., Mauger, A., Gordon, G., Keeping, T., Heath, P., Reed, G., Giles, D. Halley, S., 2013. Integrated 3D Mineral Systems Maps for Iron Oxide Copper Gold (IOCG) Deposits, Eastern Gawler Craton, South Australia, In: Jonsson E. (Eds), 12th SGA Biennial Meeting Proceedings, 1, 108-111.

Williams P.J., Kendrick M.A, Xavier R.P., 2010. Sources of ore fluid components in IOCG deposits. In: Porter T.M. (Eds) Hydrothermal Iron Oxide Copper-Gold and Related Deposits: A Global Perspective, PGC Publishing, Adelaide, 3, 107-116.

Wyborn, L.A.I., Heinrich, C.A., Jaques, A.L., 1994. Australian Proterozoic mineral systems: Essential ingredients and mappable criteria. Australasian Institute of Mining and Metallurgy Publication Series, 5, 109-1150.

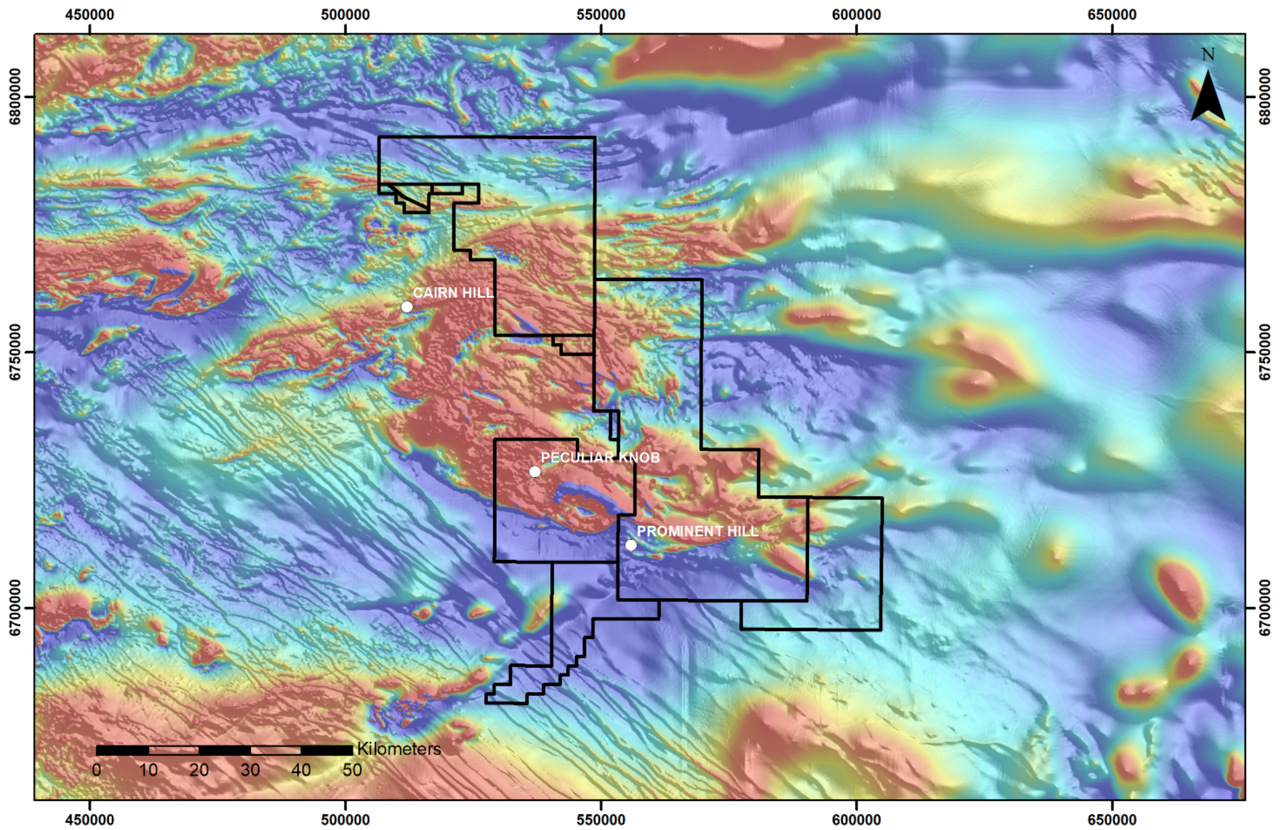

Figure 1. Explorer Challenge competition area over regional Total Magnetic Intensity (TMI) image. Mt Woods inlier, northern Gawler Craton, South Australia.

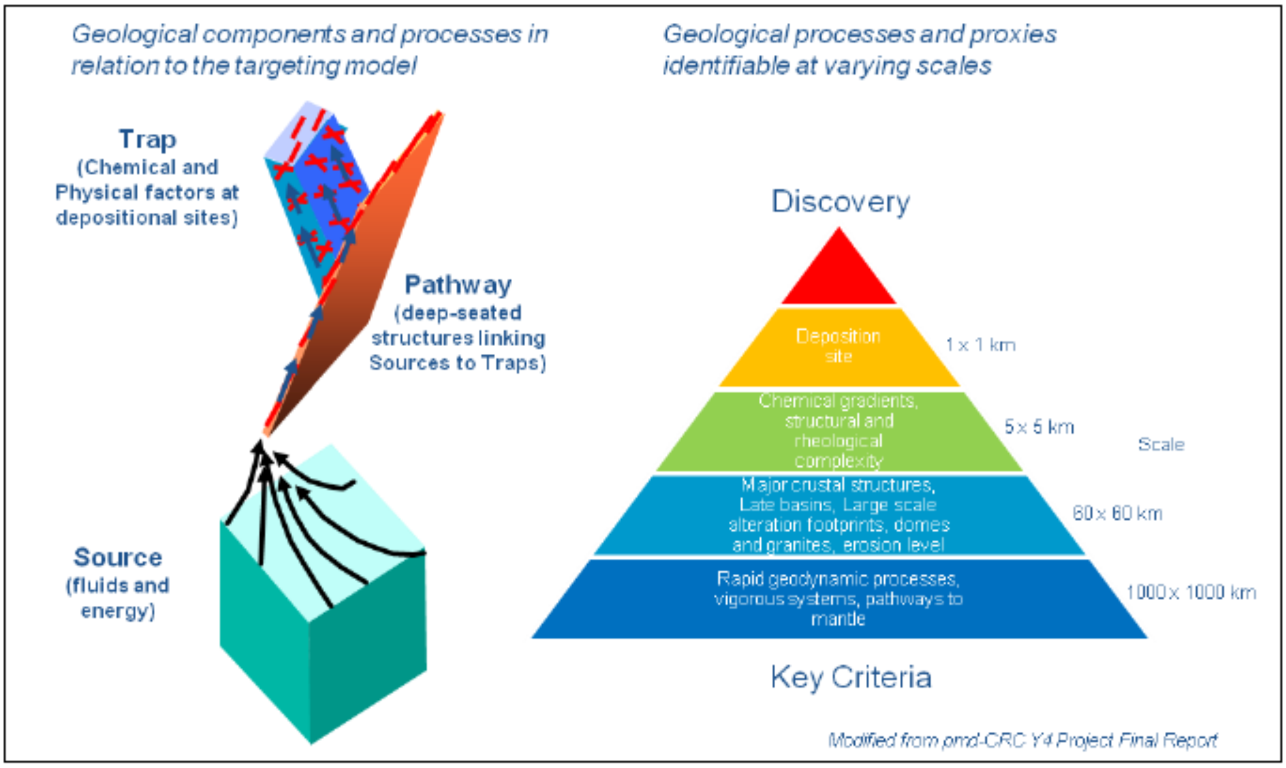

Figure 2. Illustrative example of the minerals system approach conceptual targeting model and relationship to scale.