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The science of discovery – from Exploration 1.0 to Discovery 2.0

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SUMMARY

The tools of modern exploration developed in the post war and cold war periods are no longer delivering mineral discoveries at the required rate for future economic production. The near surface search space is becoming mature. A new exploration toolkit backed by holistic systems thinking will be required to evolve Modern Exploration 1.0 into Discovery 2.0. Significant discoveries under moderate to deep cover will require new knowledge, new industry and government collaboration, new business and socio-economic models to deliver a step change in discovery rates.

To develop Discovery 2.0 we will need to deal with both the good methods and failing thinking of the past. To be truly great at discovery in 21st century geoscientists will have to step up from being simply good explorers of the modern exploration era.

Discovery thinking will need to embrace systems thinking, risk taking, and cope with ambiguity and uncertainty. Systematic area reduction may not be possible and exploration will rely on recognition of patterns more than anomalies. Lucky teams can be grown and forged by the right exploration leadership. Discoveries will come from good team based business decision making and risk management as much as brilliant geoscience and new technology. Better thinking and more thinking time will be critical factors.

Key words: systems thinking, modern exploration, discovery, risk, uncertainty, serendipity

INTRODUCTION

There have been several studies (Schodde, 2017; Rowe, 2018) that have demonstrated the drop off in significant new mineral discoveries since the 1990s. This drop in discovery rate is in spite of the largest exploration and development cycle in history, from 2003 to 2012, and has been seen in all major non-ferrous commodities and in most regions. The reason for this fall in discovery success appears two-fold:

1. The outcropping and near surface search spaces have become mature exploration environments, with at least one to many passes of systematic exploration. The exceptions to this remain jurisdictions that are environmentally off limits (e.g. Antarctica), high security risk or socio-politically quarantined.

2. The tools of 'modern exploration' (Rowe, 2018) that were used and developed post World War Two and from technologies of the Cold War (e.g. gravity gradiometers) have not been as effective at discovering economic resources at deeper targets as we had hoped for. Modern exploration includes the low level geochemistry, geophysical technology, and ore deposit knowledge.

Moreover, the modern exploration toolkit has had difficulty in discriminating early between economic and non-economic deposits. The mineral endowment identified has often proved non- viable economically, so has not resulted in increased production rates (Rowe, 2018).

The more deeply covered terrains represent the Greenfield opportunities of the 21st Century. Simply applying the failing approaches of modern exploration to this problem is unlikely to deliver the required results. Whilst the discovery toolkit for the new era will initially rely on evolution of data and technologies of the past, to be successful explorers in this under cover search space will require transformational change in technology effectiveness. Significant discoveries will require new knowledge, new industry and government collaboration, new business and socio-economic models that can deliver a step change in discovery rates. The starting point for this is an analysis of how what worked in the past actually catalysed success, what technologies can be evolved into future tools, what radically new tools may be needed and what the future might look like. This will require systems thinking, better abductive reasoning and new workflows. Then we may be in a position to re-modernise exploration into Discovery 2.0.

METHOD AND RESULTS

Discovery 2.0 will require alternative thinking. As leadership consultant Marshall Goldsmith observes "What got you here won't get you there". If we want to be great discoverers into the future, we are going to have to rethink exploration, abandon failing practices of the past and embrace new ways of thinking and doing.

There are five main failures in current thinking:

1. There is a well-worn adage that says, "mining turns rocks into money". But this was not the original purpose of mining. The first mines were for ochres for body paints used in community ceremonies. In this sense the origins of mining were tied up with cultural needs. Modern mining and exploration investment appears to have fallen into the same trap as the banking industry. Mining is not just about making money for shareholders. Mining is about creating "wealth". Wealth includes knowledge, technology and community benefits. If money is not being spent it is not doing work and so is not wealth but hoarding. To solve this greater community involvement, cross-industry collaboration and sharing should be expected. This will in turn deliver enhanced licence to operate.

2. Modern exploration technologies developments in the last century failed to live up to their expectation. In the late 20th Century the arsenal of tools at our disposal and an industry

flush with cash, technological improvements did not lead to improved rates of discovery (Dyslexic mentor article, SEG 2016). This includes methods like high powered electrical geophysics, partial leach geochemistry and data inversions. Many exploration geologists expected technological (geophysical) revolutions would dominate discovery, but this has not happened (Wood, 2016). Compilations by Richard Schodde show that it would be generous to credit geophysics as a leading factor in target selection in at most 30% of cases and for gold projects <20%. The search for silver bullets to success has often been found wanting. This is also to be expected into the future. Single technologies rarely discover on their own, discovery is nearly always a team effort. We continue to confuse technological performance with good exploration decision processes and team based risk-reward management decisions.

3. Another myth that has grown up in the investment and exploration communities is the role of the exploration genius and super teams. Investors have been encouraged to believe that attaching a list of celebrated successful explorers and directors to a project will somehow enhance success and decision making. Whilst experience is always a valuable commodity it does not always deliver wisdom for our time. A super team made up of discoverers of the past like David Lowell (Escondida, 1979) and Roy Woodall (Kambalda, 1966) would not guarantee success today. They were men of their day, working in a given search space at a given time (lower maturity). The same success in covered terrains of the future will require different thinking and different behaviours. However, many of the leadership lessons from these heroes of discovery will still be pertinent.

4. These days resource companies are deeply focussed on risk management, often without the balancing conversation about rewards. No one takes risks if there are no rewards. In their purest sense risk management and compliance are at the opposite thinking and behavioural spectrum to exploration. The danger is that risk management taken to extreme can manage out reward and success. This often comes down to the level of trust between managers and explorers, and the level of voice and acceptance of the exploration function at executive and board level. Are the current risks and rewards balanced to drive discovery? Few geoscientists fully understand the mining value chain. When managing exploration risk, we need to understand the difference between the chance of discovery, and the chance the discovery will be economic. In terms of the mining pipeline, discovery is the starting point not the finish line.

5. The resource industry is cyclical, with commodity booms often lasting less than a decade before rapidly turning to bust. This cyclical behaviour is typical of systems with delays. Commodity prices start to rise rapidly after a delayed period of low prices, triggering investment funds to finance exploration to try and increase supply. Supply then rises and eventually overshoots (delay in communication from end user back to explorer) delivering excess project capacity in the pipeline. Prices start to fall in a market that has already committed to projects. Rising cost of exploration and fear of oversupply usually precedes actual oversupply, prices collapse and exploration investment is pulled back. Eventually underinvestment (delayed feedback) in exploration drives supply shortfall kicking off the next demand cycle. Interestingly studies by Richard Schodde (2017) indicate that we see an increase in discoveries at the end of the bust. This is likely due to the bust reducing activity allowing greater thinking time and better decision making at the dawn of the next boom cycle.

   Some resource groups believe boom bust cycles can be managed or avoided, yet they are embedded in a system that shows no signs of long term structural change. It is still true that projects that hit the market at the optimal point in the cycle are the ones that win.

The only way to successfully surf the price trends is to shape the market. Few companies have this market or technology control. Companies need to control about 30% or more market share to be able to self-adjust to influence price versus supply and demand. Rare examples would be DeBeers for diamonds and Iluka for zircon.

NEW THINKING FOR DISCOVERY

How can we encourage and develop great exploration thinking and decision making for Discovery 2.0? The catalysts for success will likely be different for junior, mid-tier and major companies. They will also need to look to the future whilst standing in the present. Discovery 2.0 will be a new system with new subsystems and workflows, using new technologies and thinking. Studying exploration case studies can give us perspectives on what created past success, whilst scenario planning can provide us with alternative visions of the future and models for the future. A systems understanding will be critical.

Some of the following thinking skills and soft technology developments will be required:

- Need to understand that area selection is the key. The best exploration never finds anything in the wrong area. Exploration models and targets require candid critical assessment and peer review to improve. There needs to be strong and regular feedback loops from the results of active exploration projects. Flearning (learning through failure) needs to be in the toolkit, plus the use of pre-mortems to temper overconfidence.
- Whilst persistence is a virtue for both entrepreneurs and discoverers, teams should be honest enough to establish sound checklist of signals that quitting a project is the best course of action.
- Whilst a geoscientific approach is key, Roy Woodall also believes in serendipity; that you can create your own luck. Serendipity can be designed in. Starting with only employing the best people, empowering them, supporting them and developing them through rotational secondments from mine to exploration and back to see the full value chain. Roy also gave his people a sense of purpose, or "why", and encouraged independent and creative thinking. Many of our modern exploration tools like low level gold analysis and RC drilling were developed by motivated staff at WMC's Exploration Division. There is a role for companies in developing and preserving positive cultures and career paths for their exploration staff.
- We need to fully capture the power of systems thinking though understanding mineralising geosystems. Systems produce patterns rather than isolated anomalies. Systems behave differently at different times and can be cyclic. System causal loop and stock & flow maps can deal with the ambiguity of the unknown in process models. We will

need to use deductive, inductive and abductive reasoning for better decisions under uncertainty.

- Discoverers need to be comfortable with uncertainty and never fear the unknown. They need to deal with uncertainty and ambiguity through the use of structured exploration. The uncertainty of exploring under deep cover does not lend itself to systematic grid testing to reduce the project area. Detective tool development needs to be married to conceptual tools and a deep understanding of statistics and geological risk. Geoscientists need to understand the key differences between risk and uncertainty, complexity and chaos, the risk-reward balance, and the need to look into the future as well as understand the past.
- As with modern exploration, future exploration will need different data, technology and techniques at different scales. The most important scale is the camp scale as camp scale targeting is the key scale for area selection.
- Exploration teams need to be agile and adaptive. As innovators they need to challenge dogma and silos. They should not be afraid to drill early to answer fundamental questions or test the really obvious. Teams are forged through mutual experience and working together on challenging problems. Exploration requires leaders. True leaders can develop trust, engagement, give people a why, empower success and provide timely resources, coaching and mentoring,
- Finally, we need to develop techniques of reflective thinking, candid review and feedback to incrementally improve the system. Reflection appears to enhance the discovery rates at beginning of new boom cycles. Why not build it in for greater success to every stage of the cycle?

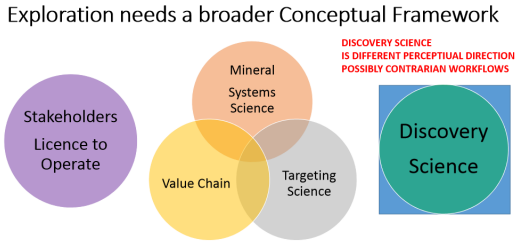

Figure 1. The evolution of Exploration 1.0 to Discovery 2.0 will require different workflows and perspectives. Discovery as a science will need new innovative thinking and collaborative agile organisational structures. Each one of the systems represented by a Venn circle will need to overlap and work together. The value chain integrates mineral economics, metallurgy and engineering into the discovery system.

CONCLUSIONS

There is huge untested opportunity for discovery of economic mineral deposits under cover. Whilst new electronic, geophysical and geochemical tools and faster data processing and AI will be important, most exploration success is ultimately driven by good decision making. Developing systems thinking, collaboration processes, the management and socio-economic tools will likely be more important to future discovery rates than any black box technology. Not all breakthrough technologies are electronic.

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