Minerals geophysics

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Back to the future

If Dr Emmett Brown, the temporal star of Spielberg's hit film of the 80s *Back to the Future* was a geologist and landed in the present day, he'd be able to observe major programmes in Australia and Canada intended to help the exploration industry confront what many regard as a crisis in discovery performance. Although both programmes appear at a distance to be passingly similar, a closer examination shows there are marked differences. Will either of these programmes be successful? Unless Brown gives us the keys to the Deloraine we can only guess. The following is brief summary of what the Australian and Canadian groups are up to, and some thoughts as to how things may unfold.

Background

The minerals exploration industry (MEI) is a complex business ostensibly directed to the discovery of new mineral resources. While government and academia provide an important supporting role to the MEI, the primary players are mining companies (Majors) who support their own internal exploration efforts, consortia of mining companies that support independent exploration groups to explore (historically called Syndicates) and small exploration-focused companies that are either supported on the stock exchange or, in a limited number of cases, by private equity funding (together here termed Juniors).

In the past 20 years Majors and Juniors have done most of the exploration work. The percentage of the total exploration spend that Majors have contributed has varied over time, due to changes in corporate leadership and commodity cycles. Overall, in terms of emphasis, the Majors have shifted to spending more on brownfields (near mine) programmes, leaving the Juniors spending more on greenfields programmes.

Starting in around 2003, the amount of funds spent on exploration rose dramatically as shown in the attached graph (Figure 1) produced by MinEx Consulting (Keenan and Schodde, 2016). What distinguishes this spike, as compared with two others in the mid-80s and 90s, is the absolute funds expended on exploration and the declining percentage of funds spent on drilling. Most importantly, in the decade 2005-2015 something over US$100B was spent, but the numbers and quality of new deposits that can be attributed to this expenditure appears to have declined.

The reasons for this decline (in part mitigated by as-yet unreported discoveries shown in light blue) have been attributed to a number of factors including:

- Maturation of exploration settings
- Increase in non-discovery costs such as administration and salaries
- Increase in exploration fees and taxes
- Increase in cost of drilling and a decrease in amount of drilling as part of the total exploration spend.

While not referenced in most discussions about exploration performance, factors that should be working in favour of enabling more discoveries include:

- Better geophysical and geochemical technologies
- Better data modelling and GIS technology
- More precompetitive data sets in many jurisdictions
- Better trained and experienced geoscientists.

In the late 2000s industry and government groups in Australia and Canada were sufficiently concerned about the lack of discoveries that they began a process to upgrade exploration efforts in their respective countries. The Canadian initiative, designated 'Footprints', was arguably simpler in scope and relied on more traditional approaches to geoscience R&D. The five-year programme kicked off in 2013 and is scheduled to be completed in 2018 – only two years away. The Australian programme has the umbrella designation 'Uncover' and the first proposals for actual work are now being prepared for consideration by sponsors. An intellectually allied endeavour, which is not formally part of the Uncover initiative, is the DETCRC. This CRC has been going since 2010 and is focused on delivering major innovations to industry in the form of

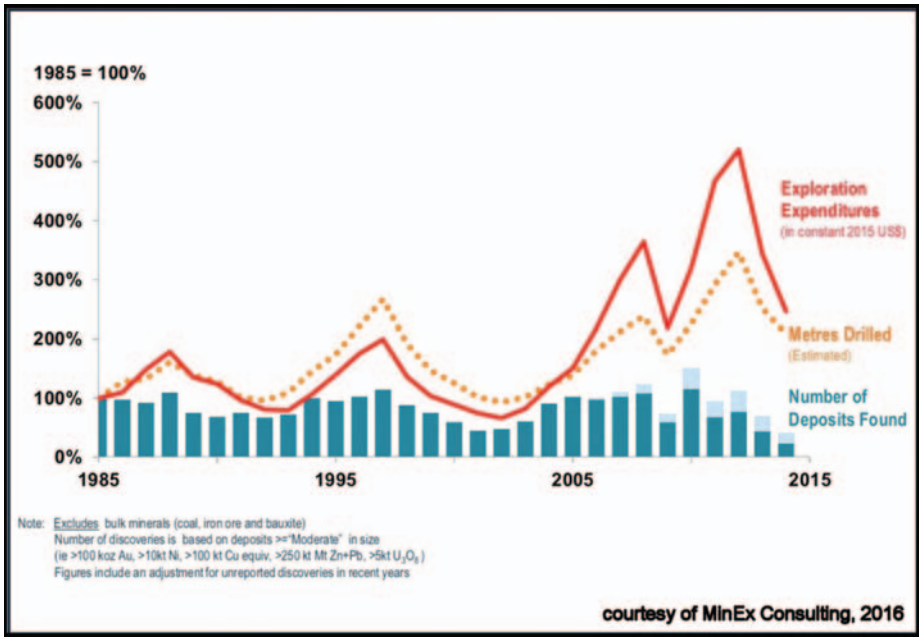

Figure 1. *Plot of global exploration expenditures, drilling and discoveries 1985–2015. Source: MinEx Consulting 2016.*

new drilling, sampling and analysis techniques. A short summary of the two national programmes is provided below.

Footprints

The primary focus of the Footprints programme is a detailed multi-parameter assessment of three deposits in Canada viz; the Canadian Malartic gold deposit in Quebec, the McArthur-Millennium unconformity uranium deposits in Saskatchewan, and the Highland Valley Cu-Mo deposit in British Columbia.

The high level objectives of the programme are to:

- Develop comprehensive and robust models of the footprints of large-scale ore-forming systems at three integrated study sites, combining geological, mineralogical, geochemical, and physical rock properties from the local to the camp scale
- Develop novel methods for integrating and interrogating multiple data sets that will enhance the exploration process and, at the same time, answer fundamental questions about the origins of large-scale ore-forming systems
- Identify the best combinations of geological, geophysical, petrophysical, mineralogical, and geochemical tools to detect the footprints of major ore-forming systems.

The industry group CMIC (Canadian Mining Innovation Council) is the overall sponsoring agency for the Footprints programme and a high-level outline of the scientific programme is shown in Figure 2 (Lesher and Hannington, 2015). A total of 24 universities were to be involved, with over 100 researchers and students engaged in various projects. The Canadian government's NSERC group (National Science and Engineering Research Council) provided $5.1M. In addition, thirty commercial sponsors (including 15 mining companies) were involved and collectively provided $7.8M in cash and in-kind.

Much of the geological, geochemical and geophysical work to be undertaken could be deemed traditional or state-of-the-art. This was almost a requirement so as to allow the programme to advance in a timely fashion. The 'newness' of the effort focused on the processing of the data sets and then bringing these results together in what are considered to be innovative ways. This stage of the programme is planned to be a joint effort between the researchers and the deposit holders.

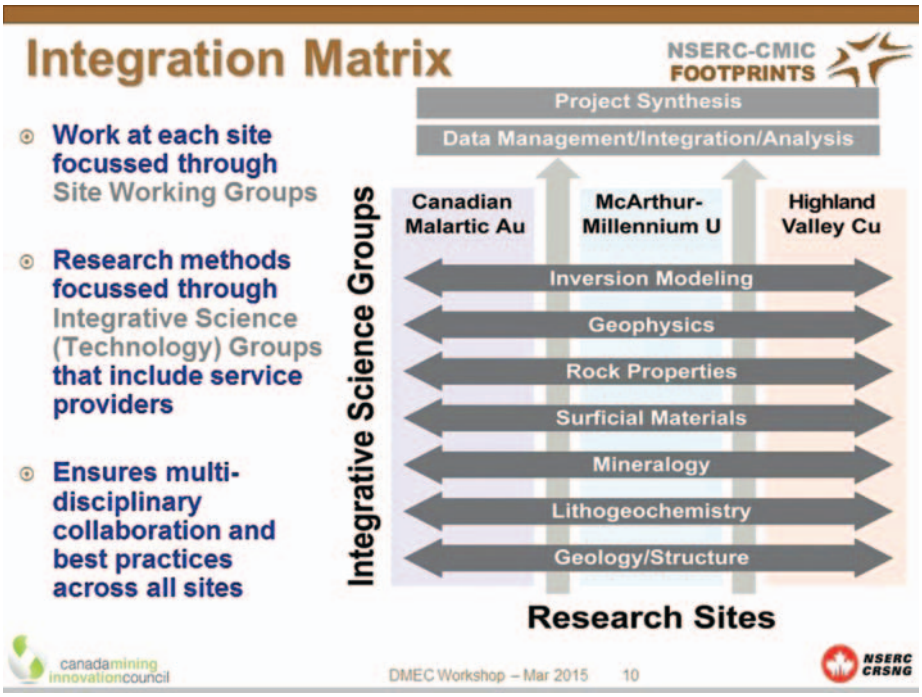

Figure 2. *CMIC Footprints science programme for study areas. Source: Lesher and Hannington, 2015.*

Uncover

The Uncover programme does not focus on specific deposits, as is the case with the Footprints programme. The programme recognises the value of the minerals system approach (Wyborn et al., 1994) and will consider how basic mineral prospectivity is defined and design search approaches best suited to the problem.

A national consensus building exercise was carried out in 2010 with the theme 'Searching the Deep Earth; The Future of Australian Resource Discovery and Utilisation' (https://www.science.org.au/news-and-events/events/future-australian-resource-discovery-and-utilisation). The final proceedings of this meeting were released in 2012. In this document the beginnings of a road map emerged, with following key topics identified:

- Characterising Australia's cover
- Investigating Australia's lithospheric architecture
- Resolving the 4D geodynamic and metallogenic evolution of Australia
- Characterising and detecting the distal footprints of ore deposits.

After a series of additional planning meetings AMIRA released the 'Roadmap for Exploration Undercover' in mid-2015. This roadmap identified a series of priority topics, the most important of which are listed below:

- Type, age and depth of cover; compilation and production of 3D geological and palaeosurface maps and layers
- Depth-to-basement and cover-characteristics; imaging from new targeted airborne National (20 km) EM surveys
- Compilation and integration of models and data to build 3D architecture and composition of the Australian lithosphere (mantle-crust-surface) from current data and knowledge
- Acceleration and completion of the national AusLamp long period MT (55 km spaced) programme
- Better understanding and definitions of mineral systems across scales for different model/deposit types and commodities
- Characterisation and mapping of whole mineral system footprints, proximal to distal, through compilation of geological, geochemical and geophysical data.

AMIRA is about to release a follow-up proposal, which will define specific projects for support by industry. Earlier this month, the Australian Commonwealth Government announced the start of a new initiative called 'Exploring for the Future', which will be allocated $100 million over the next four years to be

managed by Geoscience Australia. This initiative will hopefully give further momentum to the Uncover programme and allow it to continue to grow.

Commentary

While the Footprints and Uncover programmes both use 'national good' rhetoric, this rhetoric is used to muster favour with the local politicians as, in reality, useful knowledge about any topic passes around the world in a blindingly fast manner. In addition, almost all major explorers tread on a global stage and expect to employ 'best practice' wherever they work, regardless of the point of origin of such practice.

The Footprints programme is providing major support to the academic geoscience community in Canada and it is expected that the Uncover programme will do the same in Australia. This in itself is an outcome of value for the world of applied geoscience, especially as the industrial sector has been battling with large debts, low commodity prices and angry investors for the past three years.

While both programmes have/will generate a great deal of science and formal academic assessments of large amounts of geoscience data, I am not confident that the larger problem of improving exploration performance will be addressed by either. If the task of exploration were purely science driven then one would expect the prodigious amount of new data and ideas generated over the last decade to have made an impact on exploration performance. However, as has been observed on many occasions, exploration could be better described as an art. If this is the case then the scientific effort to improve the quality of data and data acquisition techniques (paint, brushes and canvas) will not make a substantial difference to final outcome (the quality of the painting).

On the geophysical front discussions about exploration performance are generally focused on improving technology and, sometimes, on reducing the cost of data acquisition (e.g. the current discussion around drone systems). Discussions about the process of exploration that engage the geological community at large currently seem to be suggesting that to be successful in the future the practice of the past must be emulated (e.g. Sillitoe, 1995; Meussig, 2014). This 'back to the future' approach would seem unlikely to yield, by itself, the sort of improvement in the exploration process the industry requires. But, if this advice is a call to remember the 'art of exploration' and to examine how this art was successfully practiced, then such invocations could be of real value. In this regard the interested reader is directed to a piece by John Masters, a petroleum geologist (Masters, 1991). As the conductor of an orchestra that included many geoscientific 'instruments' Masters was able to bring art and science together to create a discovery culture that was incredibly successful.

At the 1997 ASEG conference a workshop was held to mark the close of the CRC AMET. As part of this event a panel was set up to examine the question of future trends and directions for mining geophysics. Prof Gordon West was given the lead talk, with which he 'boldly' jumped 25 years into the future. He started, however, by stating how he felt geologists and geophysicists should interact in order to effectively deal with the challenges of minerals exploration.

> *But there is one vital field for mining geophysics that may easily get lost in the rush for higher tech geophysical systems. It is understanding the relationship between the geological characteristics of earth materials and the physical properties that can be remotely sensed. This can only be improved by organized, systematic feed-back from geologists who can measure the geological effectiveness (or ineffectiveness) of geophysical products to geophysicists who design the geophysical methods and surveys and (hopefully) understand the physics involved.* (West, 1997)

The current efforts to advance the science of geophysics and allied fields via major R&D programmes in Canada and Australia show that industry, government, and academia care seriously about mining and that they believe that success in exploration is a key component for the long term health of the industry. Success in exploration, however, has never been simply about the quality of the technology being used, the amount of data being acquired, or the models produced, but how these components can be blended in creative ways. In this regard the past carries important lessons for the future.

References

Keenan, J., and Schodde, R., 2016, From mineral discovery to project delivery: *SEG Newsletter*, **105**.

Lesher, C. M., and Hannington, M. D., 2015, NSERC-CMIC Exploration Footprints Network, DMEC-PDAC Seminar 2015, Toronto, Canada, 4 March 2015.

Masters, J. A., 1991, Exploration de-organization: *The Leading Edge*, **10**(1), 17–23. doi:10.1190/1.1436772

Meussig, S., 2014, The ore finders: *SEG Newsletter*, **97**, 17–19.

Sillitoe, R. H., 1995, Exploration and discovery of base- and precious-metal deposits in the circum-Pacific region during the last 25 years. Metal Mining Agency of Japan, Tokyo, Japan. http://cdn.ceo.ca.s3-us-west-2.amazonaws.com/1b6gu65-Richard+Sillitoe+-+Exploration+and+Discovery+1995.pdf

West, G. F., 1997, Into the Fourth Quarter – The Next 25 Years of Mining Geophysics. CRCAMET Research Workshop: Future Trends and Directions in Mineral Exploration Geophysics; ASEG 12th Conference and Exhibition. *Preview,* (February), 99.

Wyborn, L. A. I., Heinrich, C. A., and Jaques, A. L., 1994, Australian Proterozoic mineral systems: essential ingredients and mappable criteria. Australian Institute of Mining and Metallurgy Annual Conference, Melbourne, Proceedings, 109–115.